Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

September 8th, 2021

(data current to September 4th -7th)

Biocomplexity Institute Technical report: TR 2021-099

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About Us

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

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Overview

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

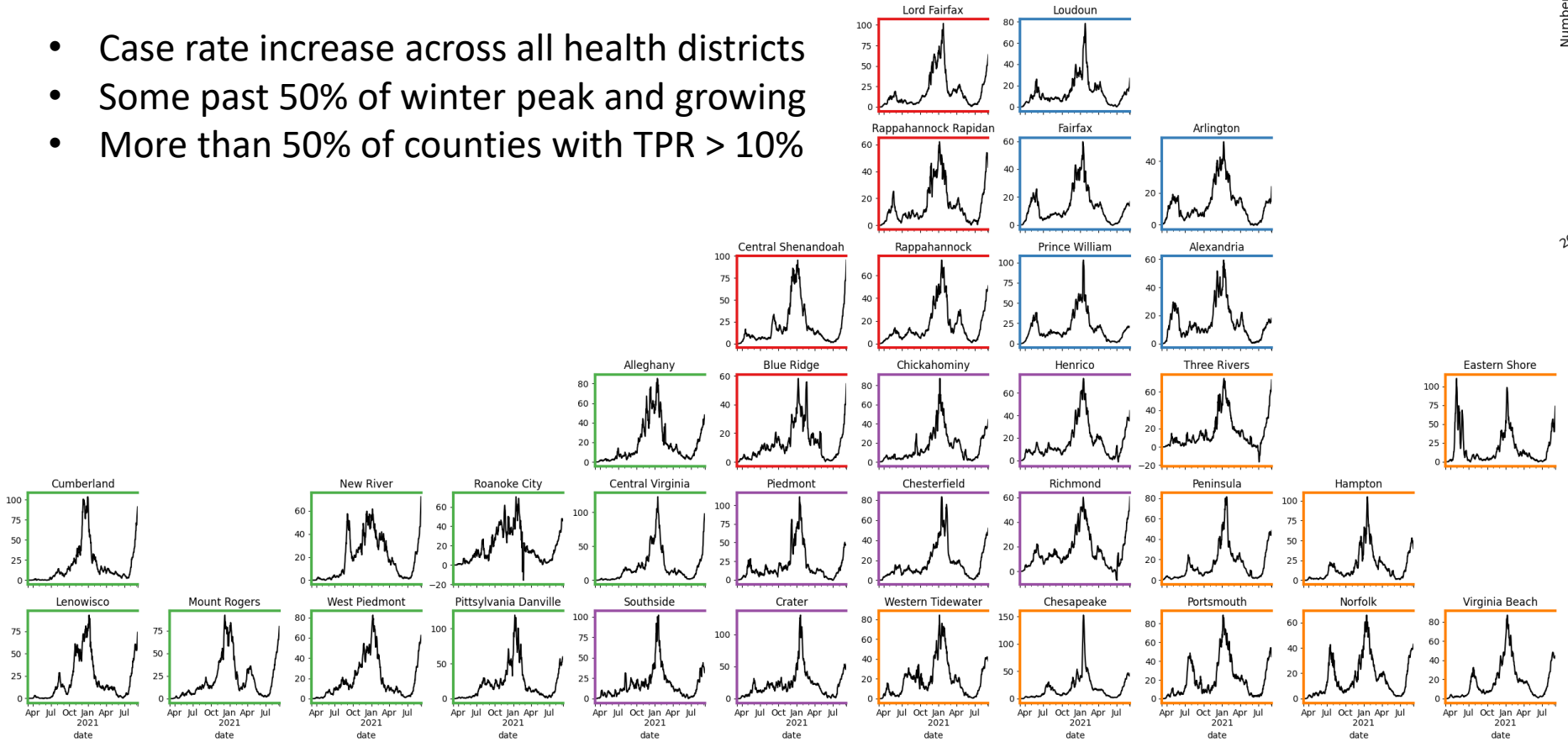
- **Case rates in Virginia continue to rise though the pace remains steady while US plateaus and some states start to decline; case rates remain very high**
- VA mean weekly incidence flat at 38/100K from 37/100K, US flat at 48/100K (from 48/100K)
- Projections continue to show significant uptick in activity, however, the reduced pace has decreased the overall impact
- Recent updates:
  - Adjustment to higher levels of assumed immunity waning (natural and vaccine)
  - Added a SeptSurge based on transmission rates from last year Labor Day to Thanksgiving with variant boosting
  - Added Fall surge scenario to capture potential rebounds and further test immunity from expanded vaccination

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

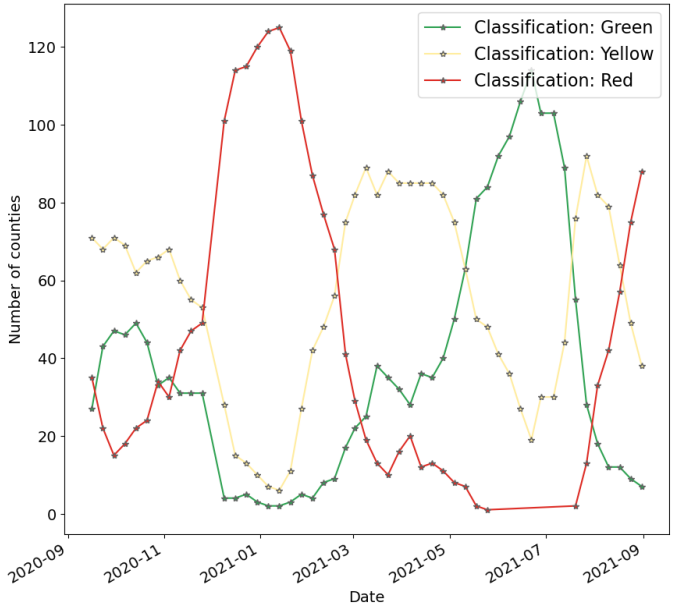
Situation Assessment

Case Rates (per 100k) and Test Positivity

- Case rate increase across all health districts
- Some past 50% of winter peak and growing
- More than 50% 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")

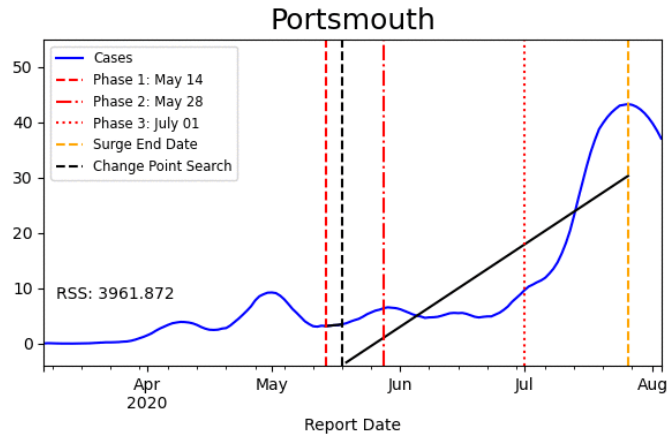
Classification	Green	Yellow	Red
date			
2021-06-28	103.0	30.0	0.0
2021-07-06	103.0	30.0	0.0
2021-07-13	89.0	44.0	0.0
2021-07-20	55.0	76.0	2.0
2021-07-27	28.0	92.0	13.0
2021-08-03	18.0	82.0	33.0
2021-08-10	12.0	79.0	42.0
2021-08-17	12.0	64.0	57.0
2021-08-24	9.0	49.0	75.0
2021-08-31	7.0	38.0	88.0

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

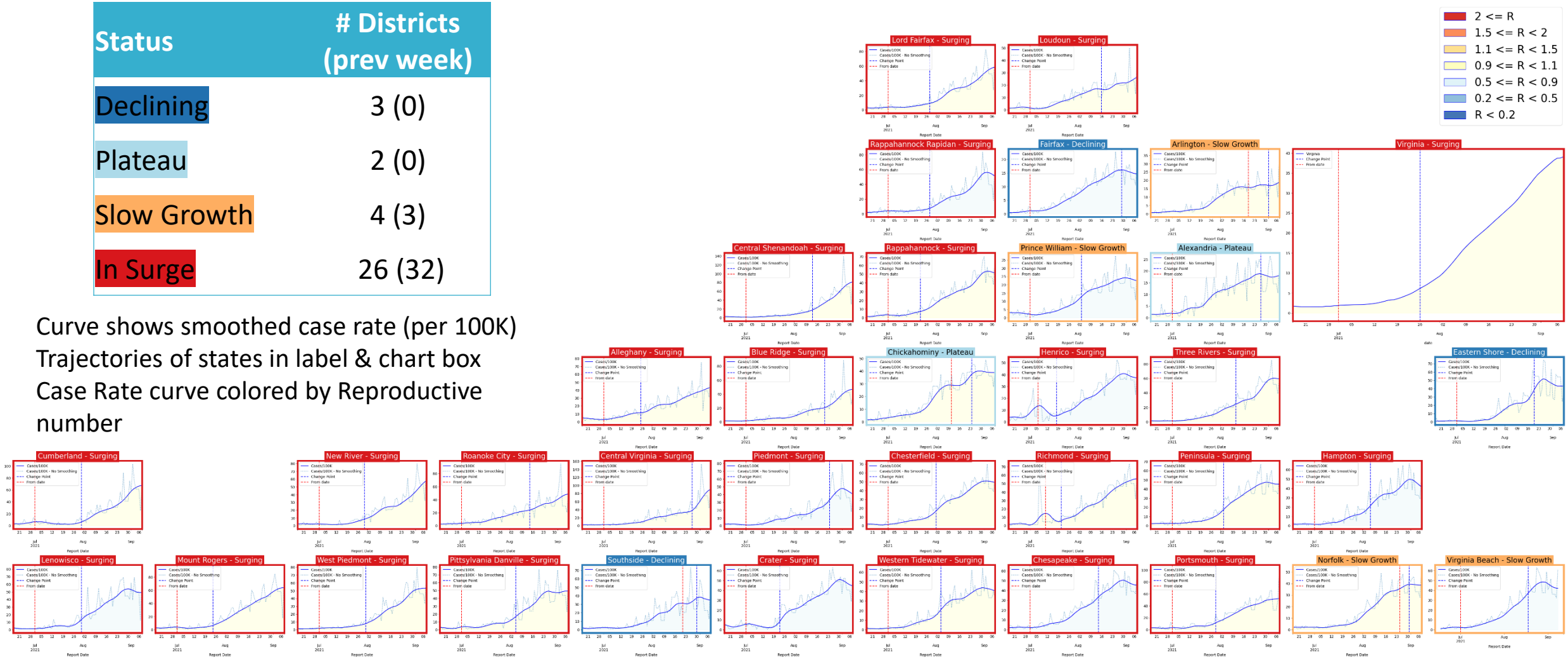


Trajectory	Description	Weekly Case Rate (per 100K) bounds	# Districts (prev week)
Declining	Sustained decreases following a recent peak	below -0.9	3 (0)
Plateau	Steady level with minimal trend up or down	above -0.9 and below 0.5	2 (0)
Slow Growth	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5	4 (3)
In Surge	Currently experiencing sustained rapid and significant growth	2.5 or greater	26 (32)

District Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	3 (0)
Plateau	2 (0)
Slow Growth	4 (3)
In Surge	26 (32)

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



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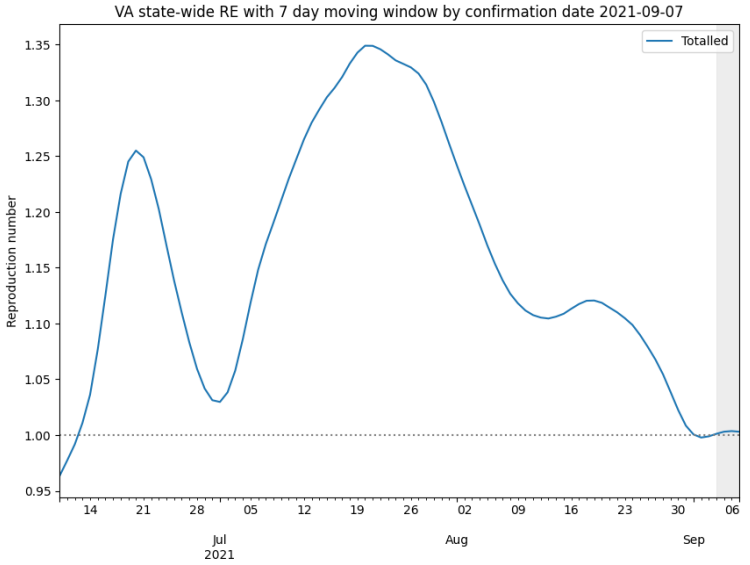
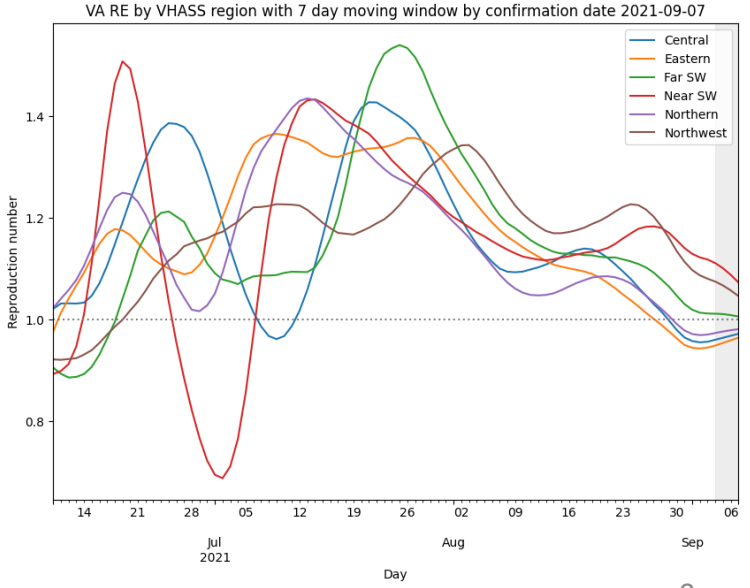
Estimating Daily Reproductive Number

Sept 6th Estimates

Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	1.003	-0.109
Central	0.908	-0.201
Eastern	0.905	-0.167
Far SW	0.936	-0.171
Near SW	1.019	-0.088
Northern	0.914	-0.198
Northwest	0.982	-0.182





Methodology

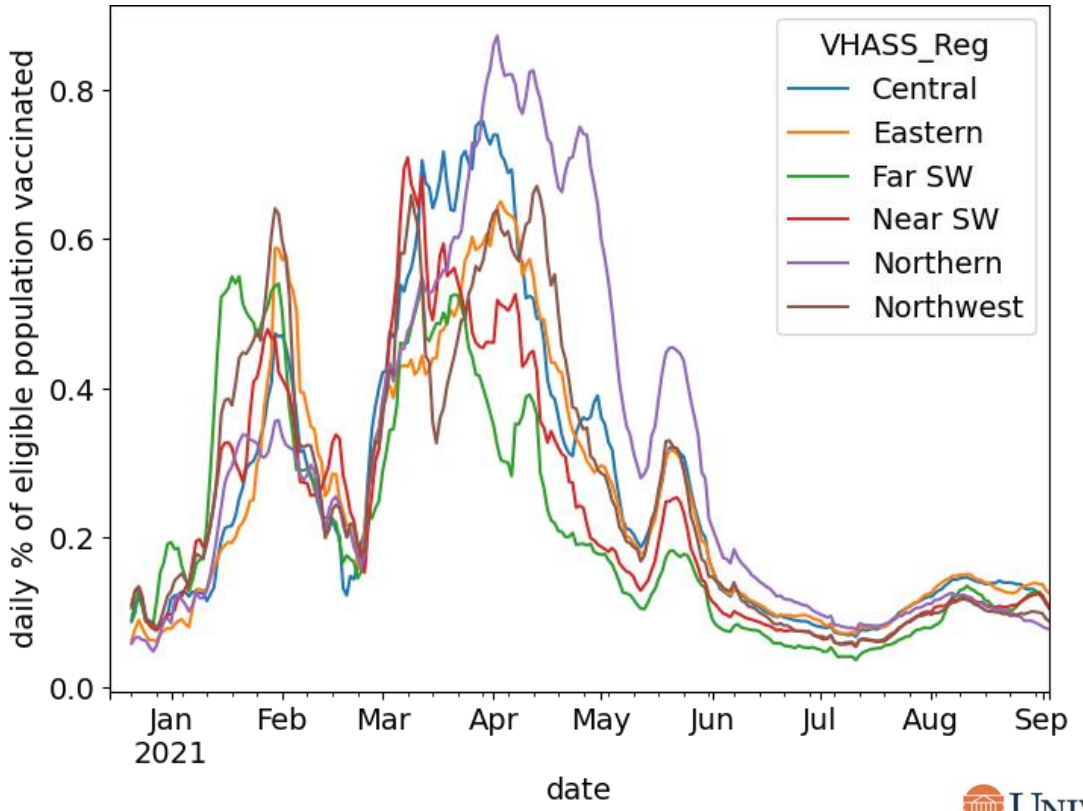
- Wallinga-Teunis method (EpiEstim[1]) for cases by **confirmation date**
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

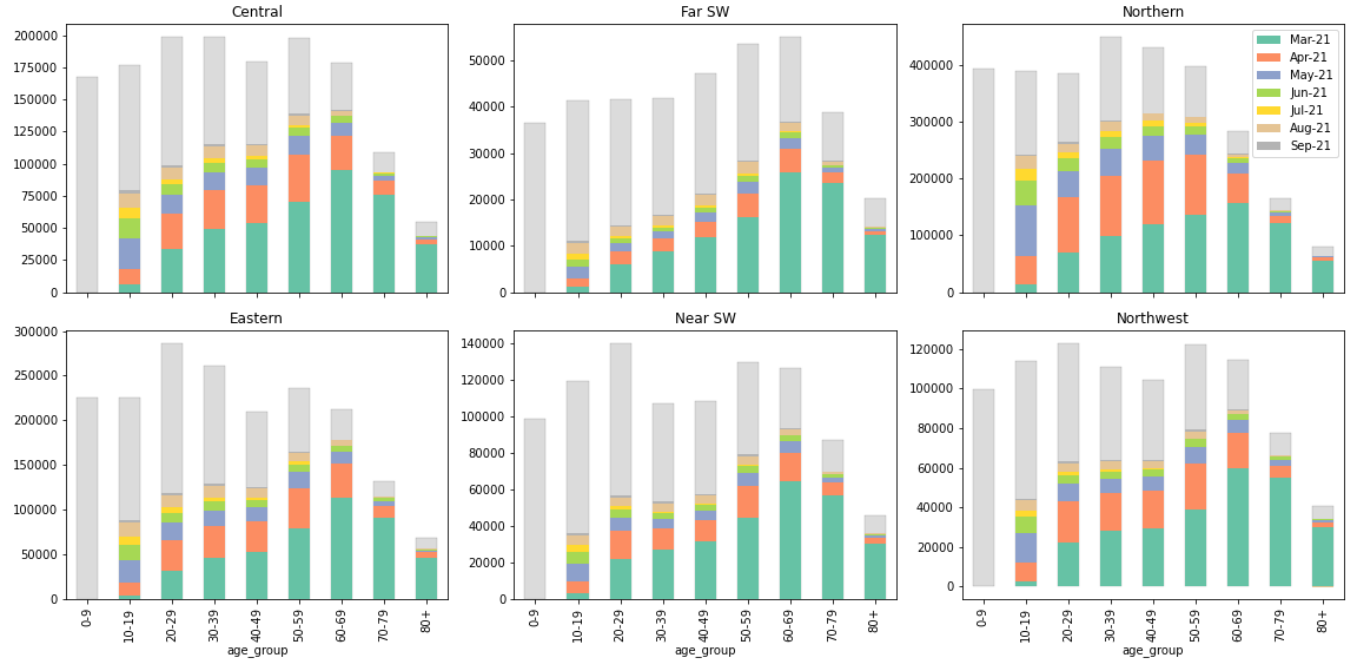
1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

Vaccination Administration Slows

Regional Vaccine courses initiated per day:

- Total counts of first dose of vaccines across regions
- Age-specific proportions of population vaccinated





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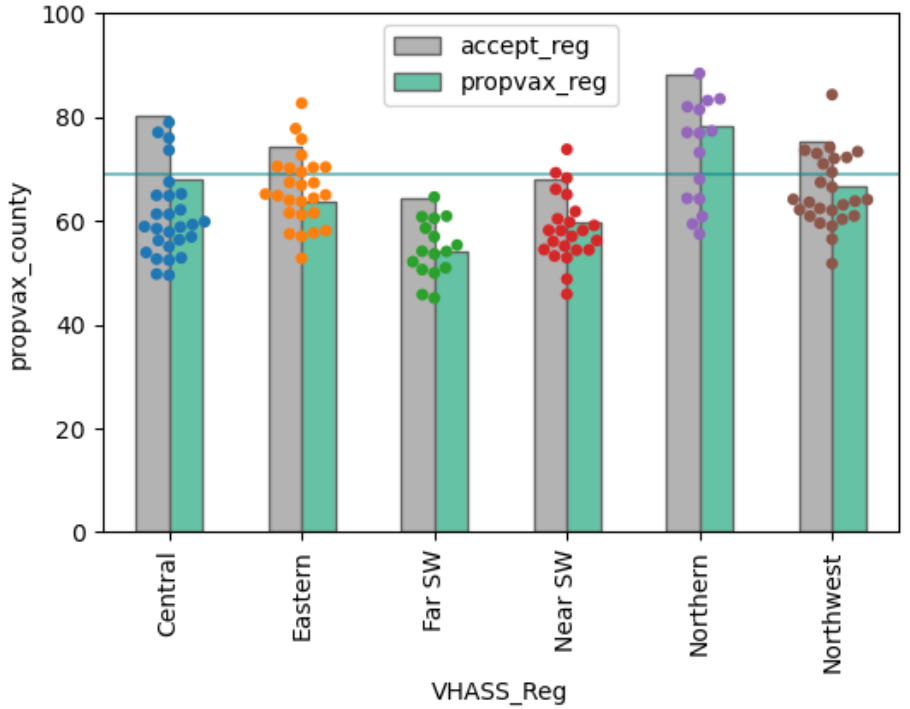
Vaccination Acceptance by Region

Corrections to surveys:

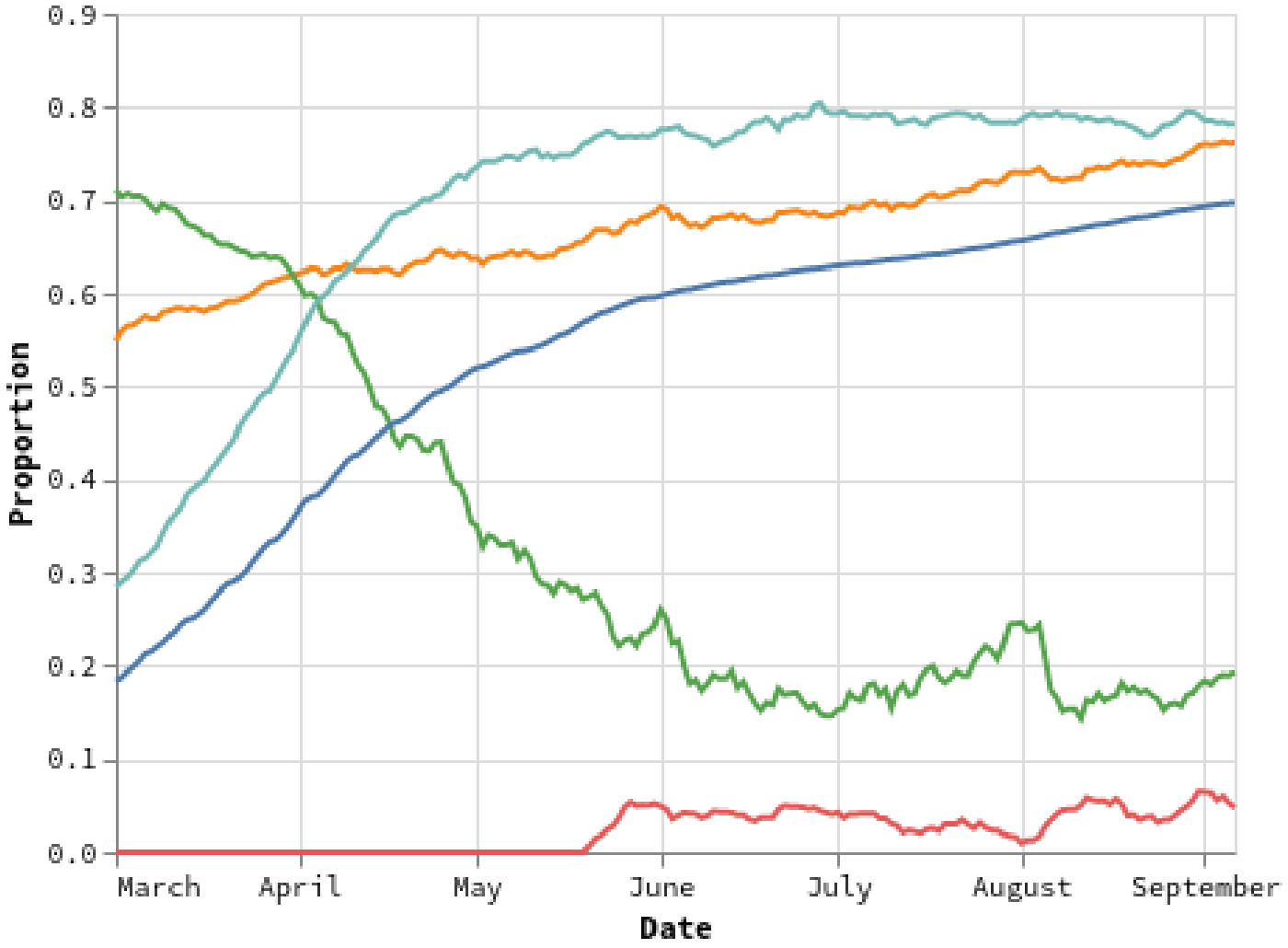
- Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
- Correction approach:
  - Calculate an over-reporting fraction based on reported vaccinations compared to VDH administration data
  - Cross-validate coarse corrections against HPS survey at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

Region	COVIDcast accepting corrected	VDH proportion pop vaccinated
Central	78%	68%
Eastern	75%	64%
Far SW	64%	54%
Near SW	68%	60%
Northern	89%	78%
Northwest	75%	67%
Virginia	**79%**	**69%**



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 adjusted to include scheduled appoinments

- Steady rise in acceptance over the past couple months
- Unvaccinated Acceptance shows ~20% of those who are unvaccinated are definitely or probably willing to be vaccinated
- Scheduled appointments for vaccination has increased through August but seems to be leveling off.

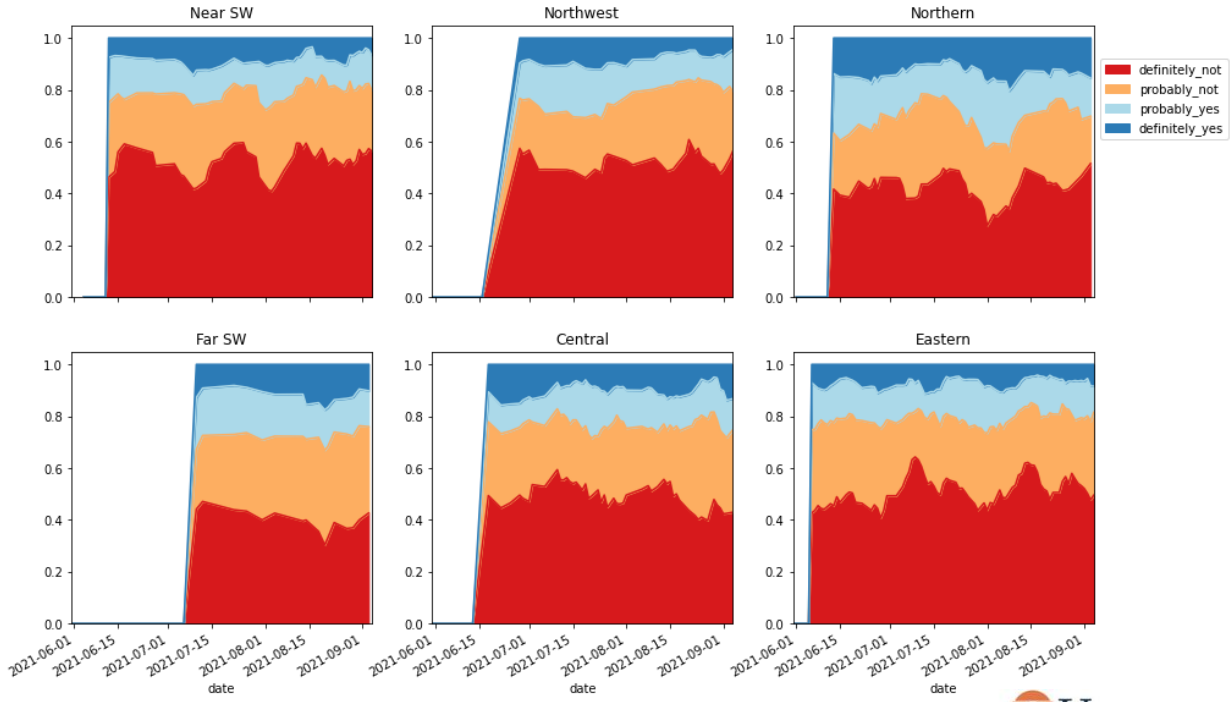
Data Source: https://covidcast.cmu.edu

Vaccine Acceptance by Region- COVIDcast

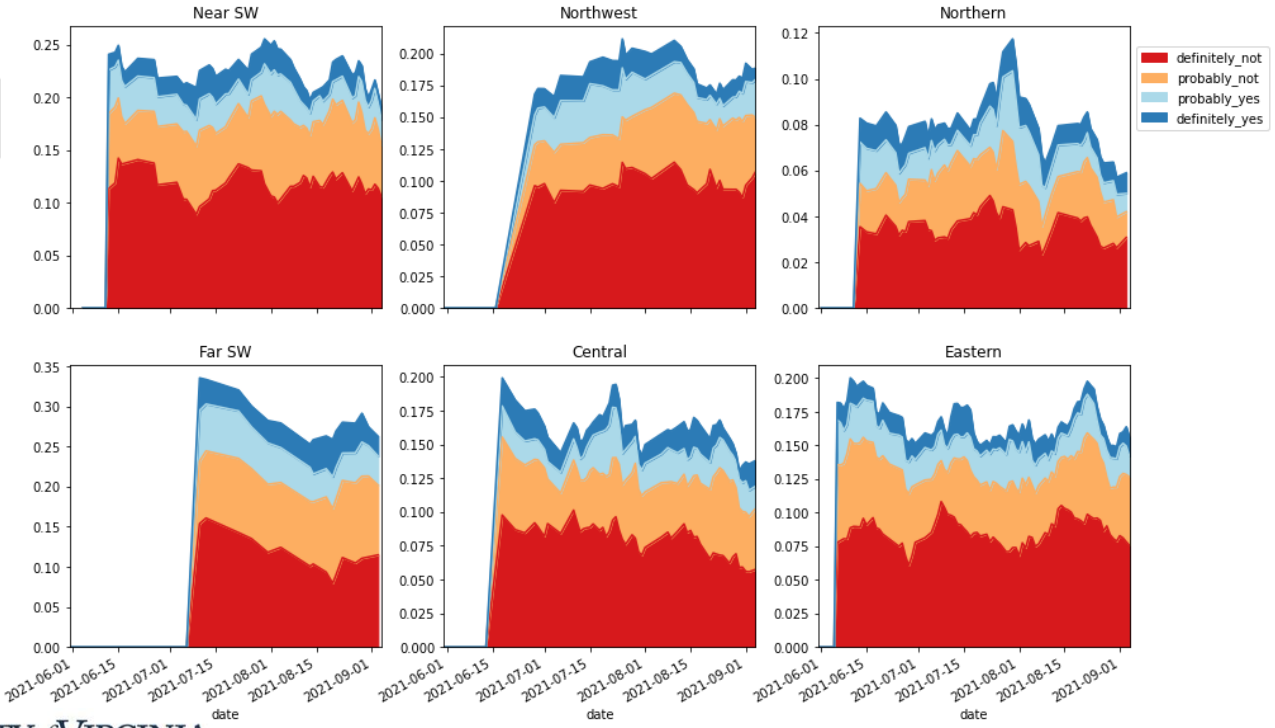
Levels of Acceptance and potential acceptance in flux:

- 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



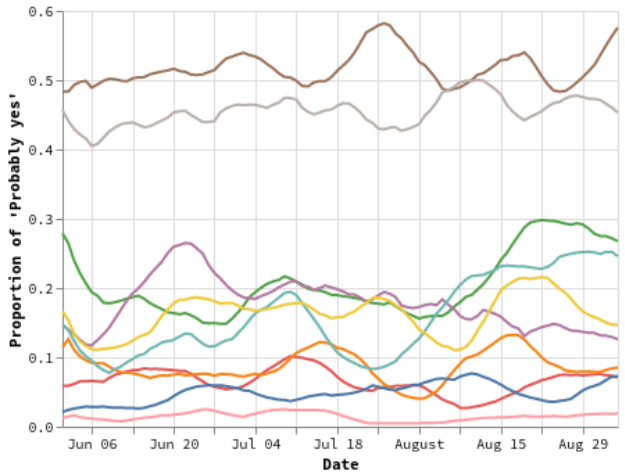
All Respondents



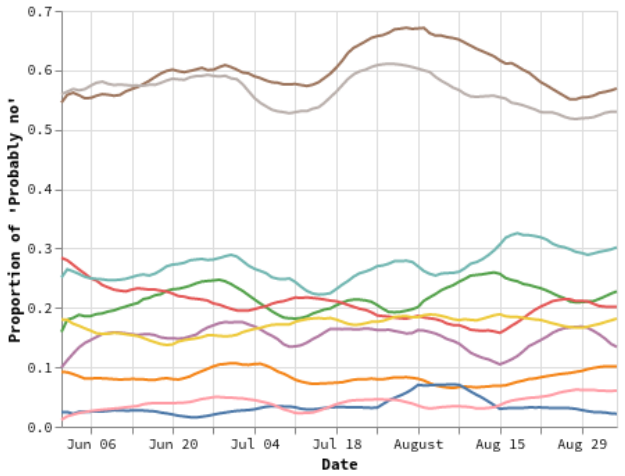
Data Source: https://covidcast.cmu.edu

Reasons for Hesitancy by Likeliness to Accept

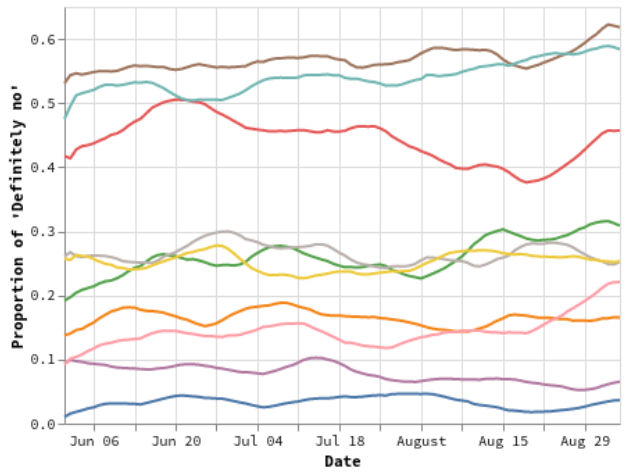
Probably Yes

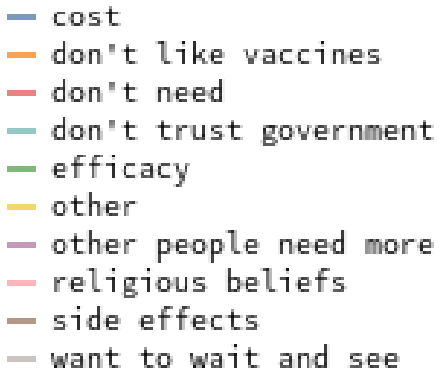


Probably No



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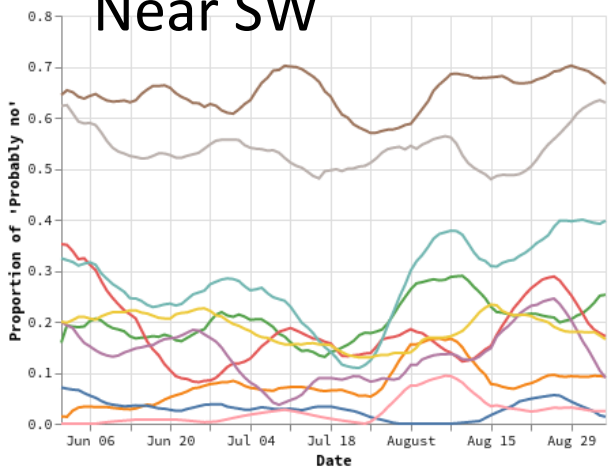
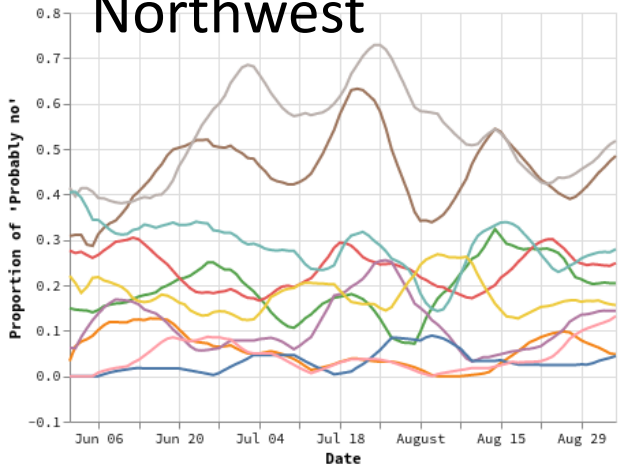
Data Source: https://covidcast.cmu.edu

Reasons for Hesitancy of Probably No by Region

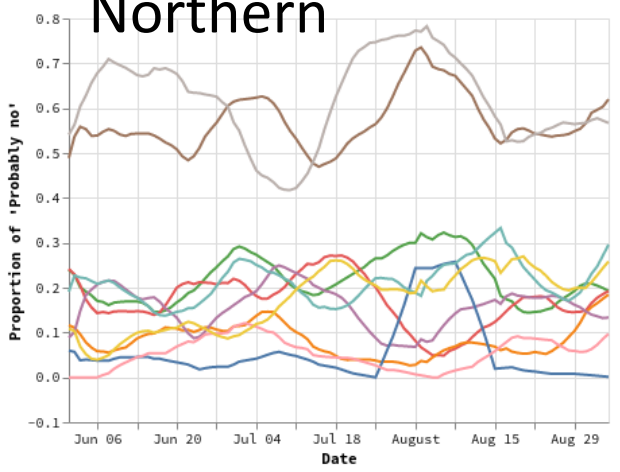
Near SW

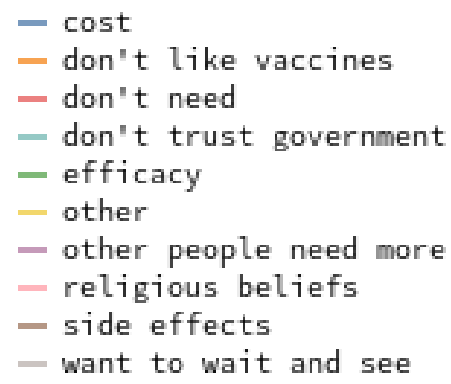


Northwest

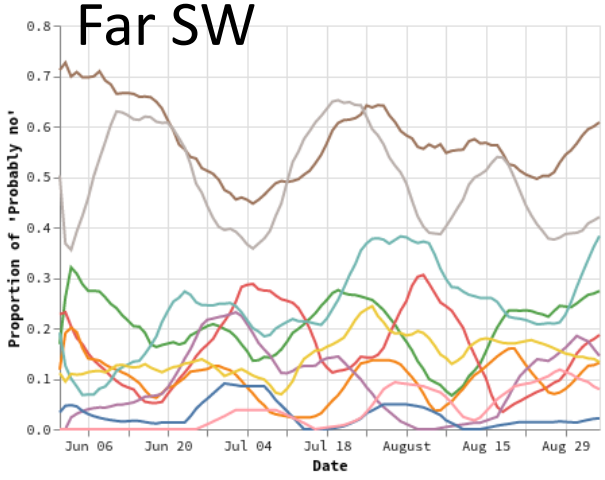


Northern

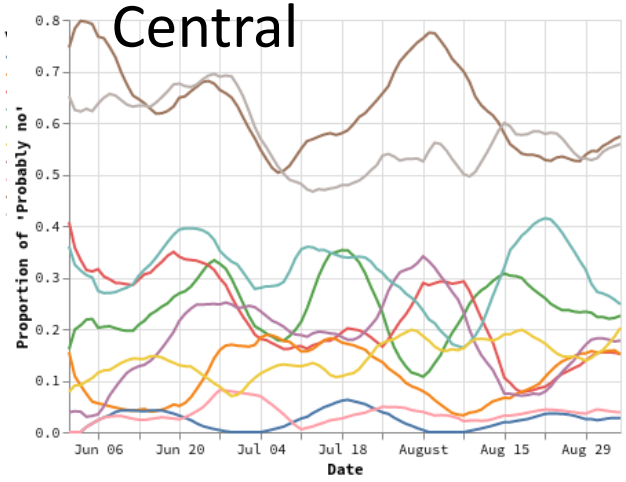




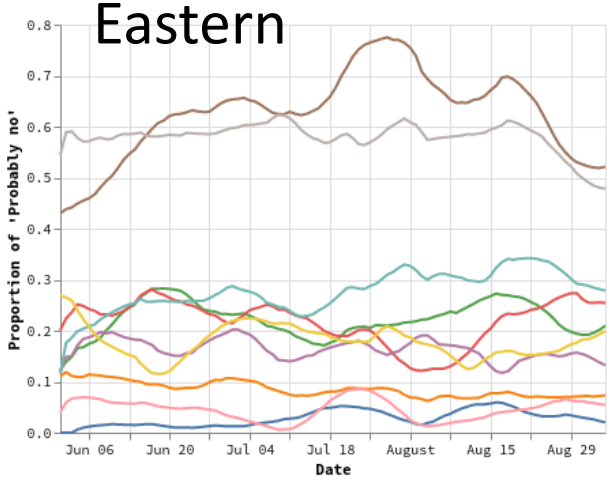
Far SW



Central



Eastern



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

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

Mask Usage Increases

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

- State-wide continues to rise, now outpaces US (64% vs. 62%)
- Progress in some counties has stalled or declined

VIRGINIA COUNTIES

COUNTY	CHANGE LAST 7 DAYS	PER 100	HISTORICAL TREND 8/09 – 9/06
United States	↑ +4.22%	62.63%	
Virginia	→ +2.77%	63.83%	
Arlington County, VA	↓ −23.07%	54.46%	
Norfolk, VA	↓ −15.21%	61.11%	
Chesapeake, VA	↑ +7.06%	61.54%	
Virginia Beach, VA	↑ +5.83%	61.77%	
Albemarle County, VA	↑ +7.96%	64.00%	
Chesterfield County, VA	→ −3.32%	64.09%	
Hampton, VA	↓ −8.05%	68.60%	
Henrico County, VA	→ +4.33%	70.33%	
Prince William County, VA	↓ −5.69%	71.80%	
Richmond, VA	→ +2.50%	72.10%	
Stafford County, VA	↑ +33.20%	72.30%	
Loudoun County, VA	→ +2.32%	72.77%	
Newport News, VA	↑ +5.60%	75.58%	
Fairfax, VA	→ −2.51%	75.98%	

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

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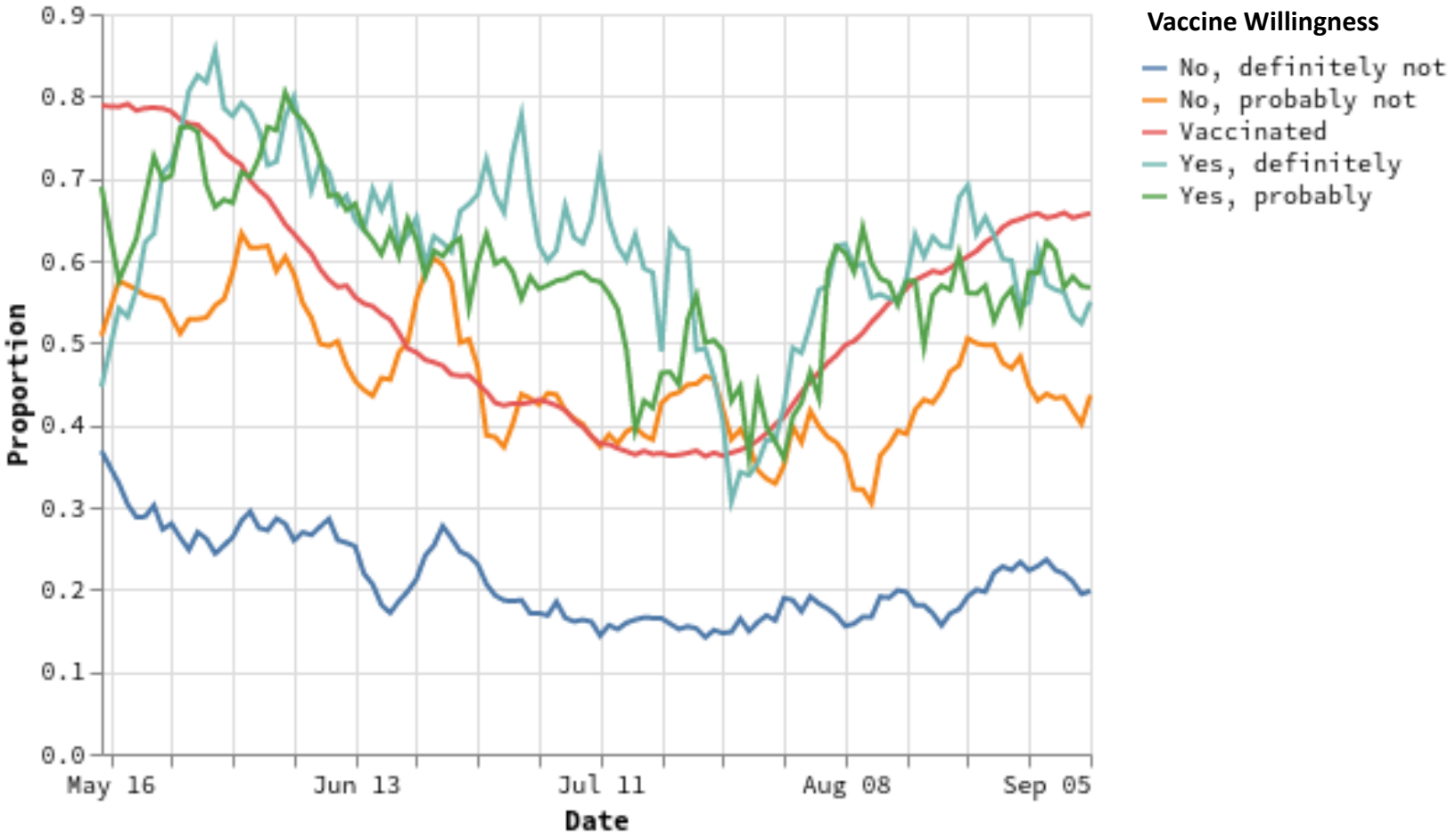
Mask Wearing by Vaccine Willingness

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
- Slight decline for No, Probably Not
- Vaccinated continues to have higher mask wearing than unvaccinated across all tiers of willingness



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

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SARS-CoV2 Variants of Concern

Emerging new variants will alter the future trajectories of pandemic and have implications for future control

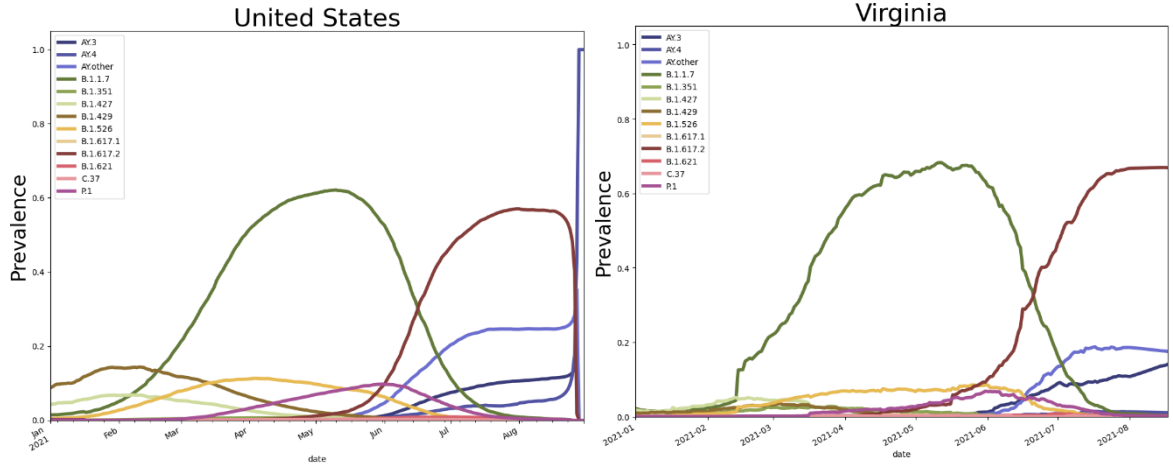
- Emerging variants can:
  - Increase transmissibility
  - Increase severity (more hospitalizations and/or deaths)
  - Limit immunity provided by prior infection and vaccinations
- Genomic surveillance remains very limited
  - Challenges ability to estimate impact in US to date and estimation of arrival and potential impact in future

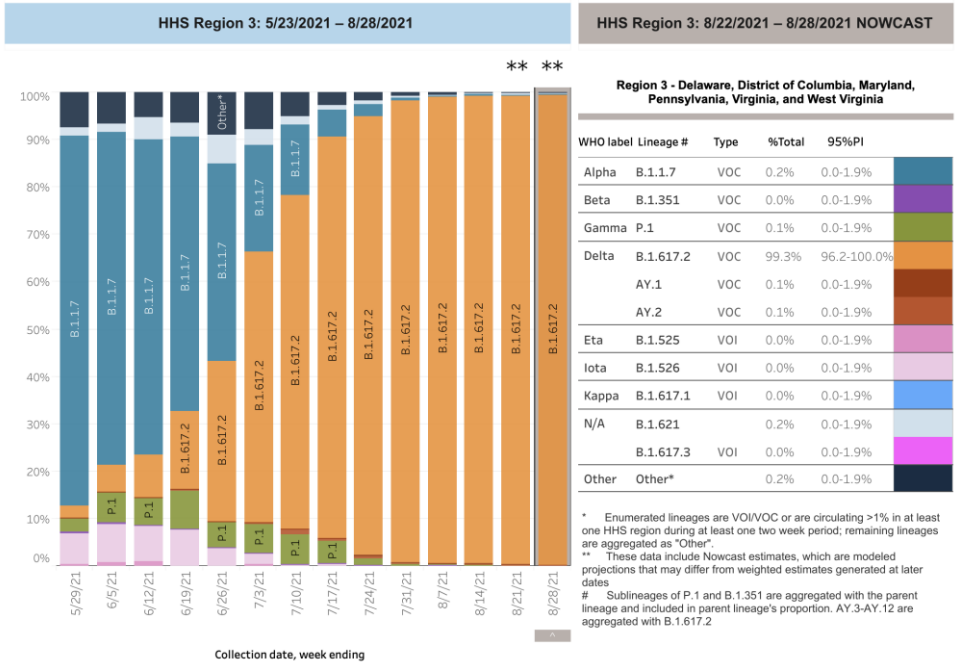
	New WHO Name	Transmissibility	Immune Evasiveness	Vaccine Effectiveness^
Ancestral		—	—	✓
D614G		+	—	✓
B.1.1.7	Alpha	+++	—	✓
B.1.351	Beta	+	++++	✓
P.1	Gamma	++	++	✓
B.1.429	Epsilon	+	+	✓
B.1.526	Iota	+	+	✓
B.1.617.2	Delta	++++*	++#	✓

*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





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

WHO label	Lineage #	Type	%Total	95%PI
Alpha	B.1.1.7	VOC	0.2%	0.0-1.9%
Beta	B.1.351	VOC	0.0%	0.0-1.9%
Gamma	P.1	VOC	0.1%	0.0-1.9%
Delta	B.1.617.2	VOC	99.3%	96.2-100.0%
	AY.1	VOC	0.1%	0.0-1.9%
	AY.2	VOC	0.1%	0.0-1.9%
Eta	B.1.525	VOI	0.0%	0.0-1.9%
Iota	B.1.526	VOI	0.0%	0.0-1.9%
Kappa	B.1.617.1	VOI	0.0%	0.0-1.9%
N/A	B.1.621		0.2%	0.0-1.9%
	B.1.617.3	VOI	0.0%	0.0-1.9%
Other	Other*		0.2%	0.0-1.9%

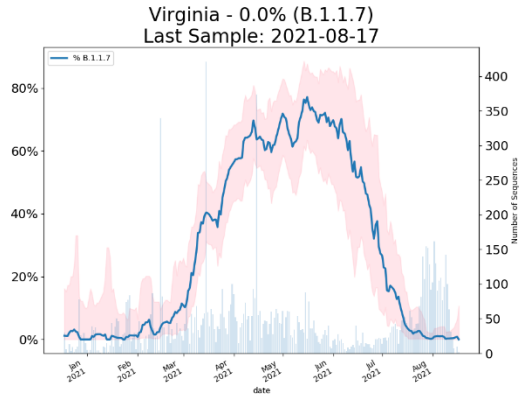
* Enumerated lineages are VOI/VOC or are circulating >1% in at least one HHS region during at least one two week period; remaining lineages are aggregated as "Other".
** These data include Nowcast estimates, which are modeled projections that may differ from weighted estimates generated at later dates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

CDC [CDC Variant Tracking](#)

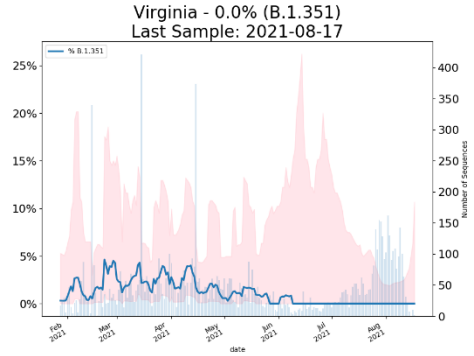
SARS-CoV2 Variants of Concern

Previous Variants

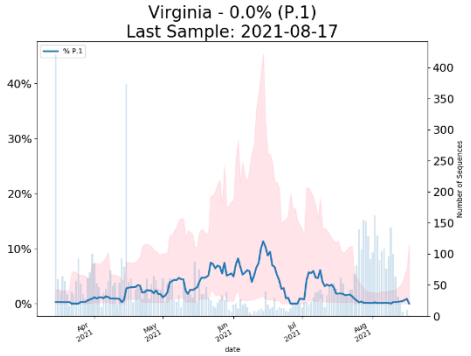
Alpha α - Lineage B.1.1.7



Beta β - Lineage B.1.351



Gamma γ - Lineage P.1



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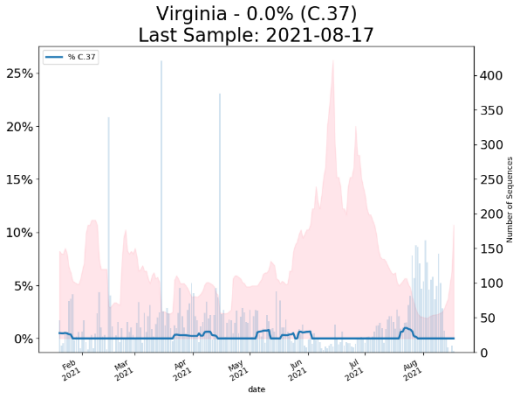
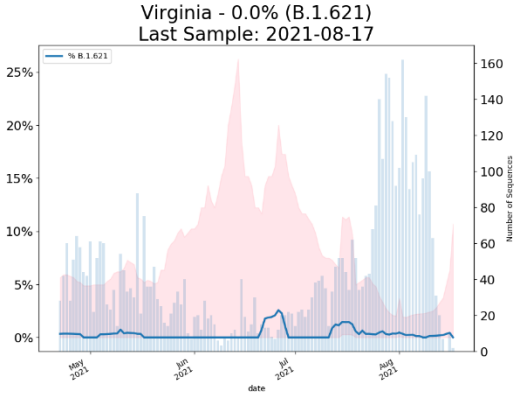
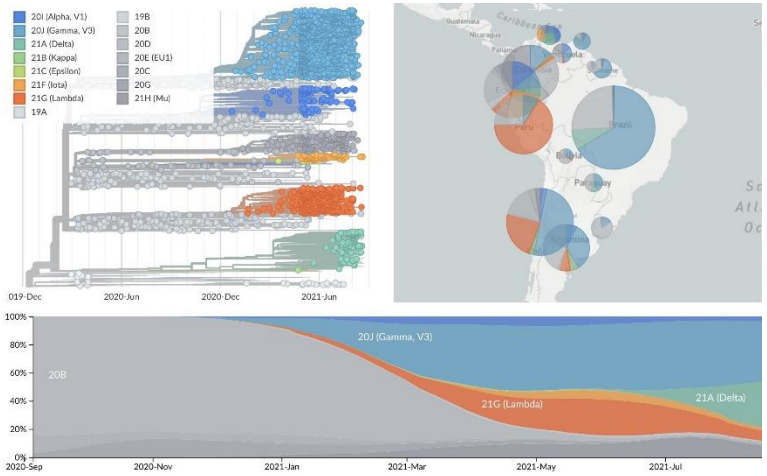
Emerging Variants

Lambda λ - Lineage C.37



Mu μ - Lineage B.1.621



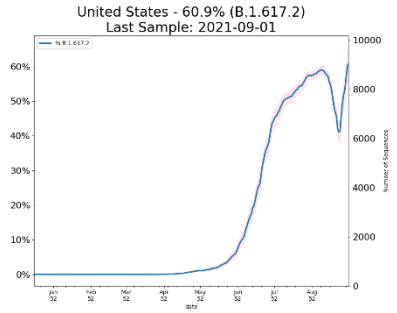


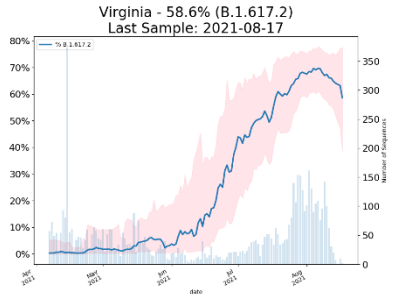
Delta seems to be outcompeting Lambda and Mu in South America
Trevor Bedford Tweet & Nextstrain Analysis

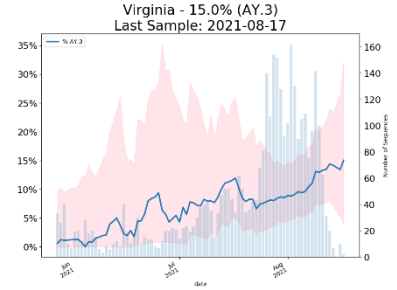
SARS-CoV2 Variants of Concern

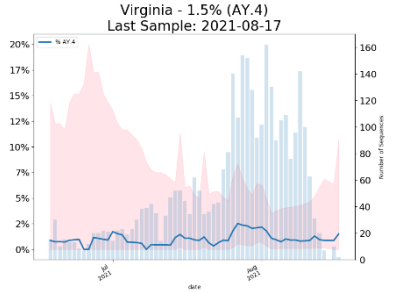
Delta δ - Lineage B.1.617.2 and related subvariants

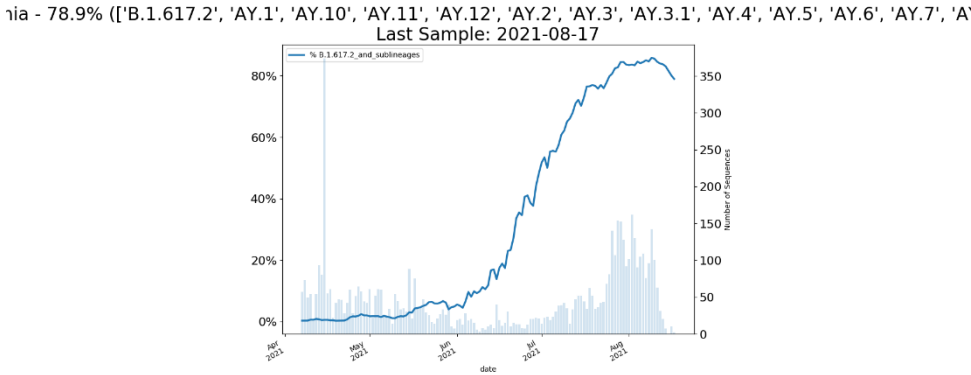
- Delta plus δ+ lineage which contains the K417N mutation is emerging as a sub-variant that is even more transmissible; declared a VoC in India
- Delta variant now dominates most of Europe and US
- CDC recommends resumption of mask wearing indoors due to reports of breakthrough infections of the vaccinated 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
- Subvariants AY.3 (15%) and AY.4 (1.5%) of Delta are more prevalent, these subvariants are mainly clustered in the US, others mainly outside of US











Main delta and all other subvariants

Variants & Vaccines

1. Pfizer Vaccine was estimated to have high vaccine effectiveness in pregnant women: 96% effectiveness against documented infection and 97% effectiveness against symptomatic infection 7–56 d after receipt of the second vaccine
2. CDC: Community vaccination, in coordination with testing strategies and other prevention measures, is critical to protecting pediatric populations from SARS-CoV-2 infection and severe COVID-19.
3. CDC: Preventive measures to reduce transmission and severe outcomes in children and adolescents are critical, including vaccination, universal masking in schools, and masking by persons aged ≥2 years in other indoor public spaces and child care centers.
4. Australian study predicts vaccinating over 85% of the population including children would likely be needed to achieve population protection at the most plausible effective reproduction number
5. University of California – San Diego healthcare worker study shows high vaccine effectiveness across the months until July when Delta began to dominate

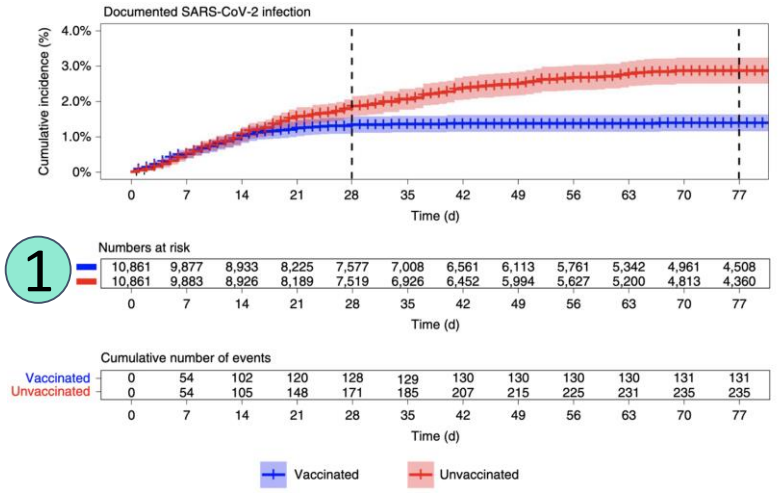
5

Table 1. Symptomatic SARS-CoV-2 Infection and mRNA Vaccine Effectiveness among UCSDH Health Workers, March through July 2021.*

	March	April	May	June	July
UCSDH workforce — no. of persons	18,964	18,992	19,000	19,035	19,016
Vaccination status — no. of persons					
Fully vaccinated†	14,470	15,510	16,157	16,426	16,492
mRNA-1273 (Moderna)	6,608	7,005	7,340	7,451	7,464
BNT162b2 (Pfizer–BioNTech)	7,862	8,505	8,817	8,975	9,028
Unvaccinated	3,230	2,509	2,187	2,059	1,895
Percentage of workers fully vaccinated	76.3	81.7	85.0	86.3	86.7
Symptomatic Covid-19					
Fully vaccinated workers	3	4	3	5	94
Unvaccinated workers	11	17	10	10	31
Percentage of cases in fully vaccinated workers	21.4	19.0	23.1	33.3	75.2
Attack rate per 1000 (95% CI)					
Fully vaccinated workers	0.21 (0.21–0.47)	0.26 (0.26–0.50)	0.19 (0.21–0.40)	0.30 (0.31–0.53)	5.7 (5.4–6.2)
Unvaccinated workers	3.4 (2.1–5.9)	6.8 (4.5–10.6)	4.6 (2.6–8.2)	4.9 (2.9–8.7)	16.4 (11.8–22.9)
Vaccine effectiveness — % (95% CI)	93.9 (78.2–97.9)	96.2 (88.7–98.3)	95.9 (85.3–98.9)	94.3 (83.7–98.0)	65.5 (48.9–76.9)

* UCSDH denotes University of California San Diego Health.
† Data are the total number of workers who had received two doses of an mRNA vaccine as of the last day of the month.

1



An observational cohort study of pregnant women aged 16 years or older, with no history of SARS-CoV-2, who were vaccinated between 20 December 2020 and 3 June 2021. A total of 10,861 vaccinated pregnant women were matched to 10,861 unvaccinated pregnant women using demographic and clinical characteristics.
https://www.nature.com/articles/s41591-021-01490-8

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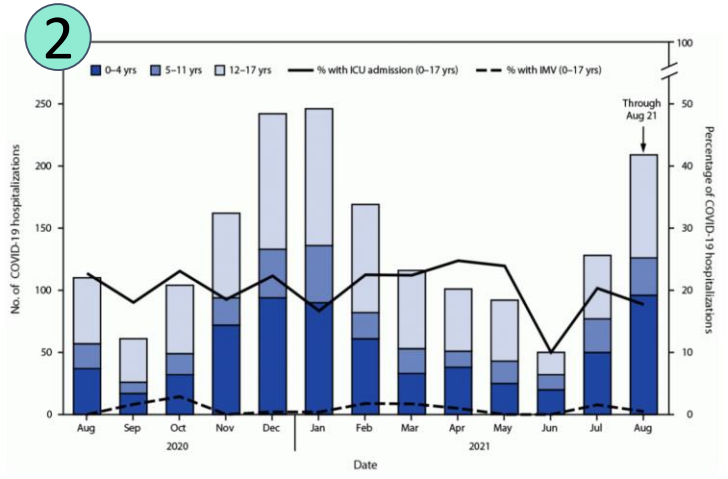

COVID-19 cases, emergency department visits, and hospital admissions increased from June to August 2021 among persons aged 0-17 years. Emergency department visits and hospital admissions in a 2-week period in August 2021 were higher in states with lower population vaccination coverage and lower in states with higher vaccination coverage.
https://www.cdc.gov/mmwr/volumes/70/wr/mm7036e1.htm?s_cid=mm7036e1_w

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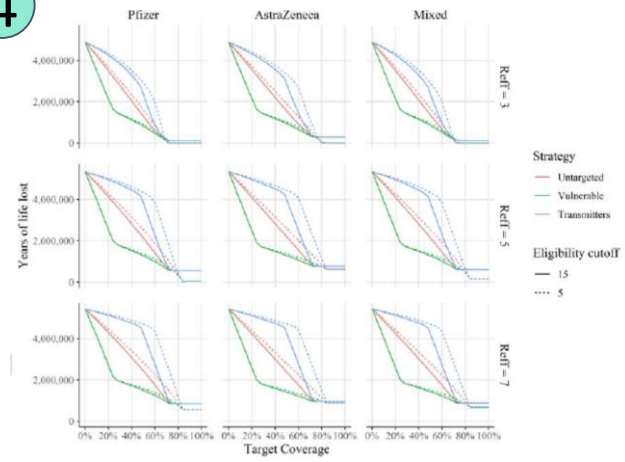
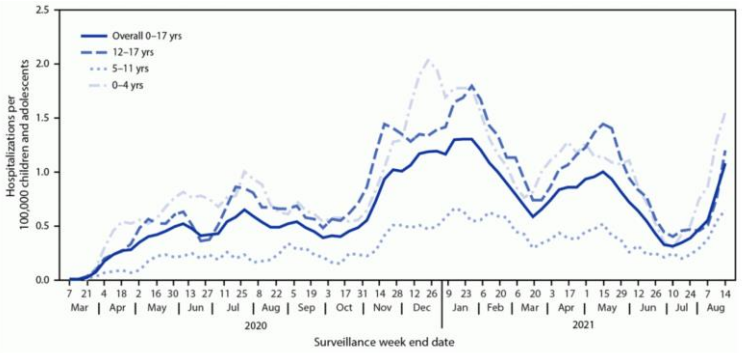


Australian modeling study investigates vaccination levels necessary to protect population. Gives potentially valuable parameterization to different vaccine schedules
https://pubmed.ncbi.nlm.nih.gov/34477236/

3



Weekly COVID-19–associated hospitalization rates among children and adolescents rose nearly five-fold during late June–mid-August 2021, coinciding with increased circulation of the highly transmissible SARS-CoV-2 Delta variant.
https://www.cdc.gov/mmwr/volumes/70/wr/mm7036e2.htm?s_cid=mm7036e2_w

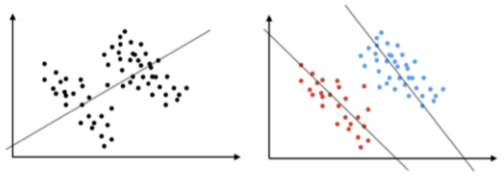
Vaccine Efficacies – Simpson's Paradox

Simpson's Paradox Explained

Blog Post: https://www.covid-datascience.com/post/israeli-data-how-can-efficacy-vs-severe-disease-be-strong-when-60-of-hospitalized-are-vaccinated

Simpson's paradox explained

There are various nice explanations of Simpson's paradox online, including here and here. I will borrow a plot from the latter reference and give a simple illustration:



A visual example: the overall trend reverses when data is grouped by some colour-represented category.

Example from Israeli Data

Vaccine efficacy vs. severe disease for younger (<50yr) = 1 - 0.3/3.9 = ***91.8%***
Vaccine efficacy vs. severe disease for older (>50yr) = 1- 13.6/90.9 = ***85.2%***

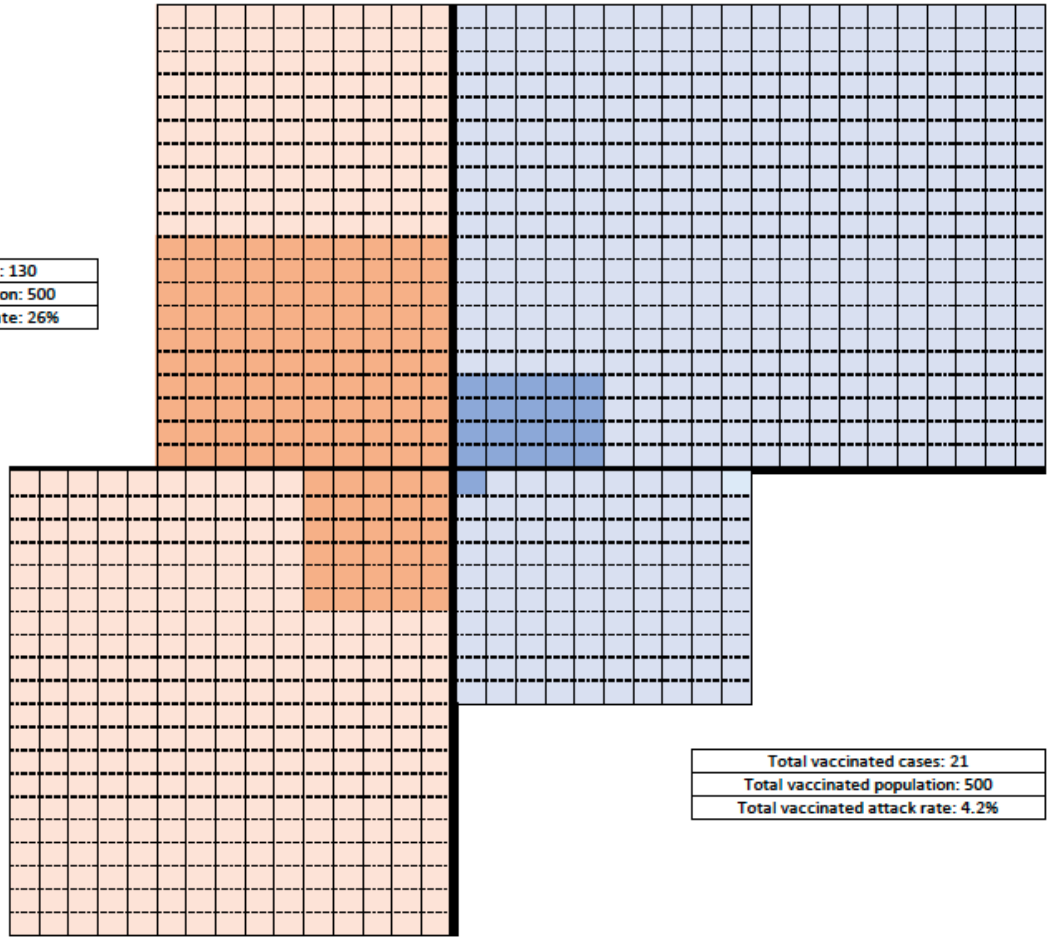
Age	Population (%)		Severe cases		Efficacy
	Not Vax %	Fully Vax %	Not Vax per 100k	Fully Vax per 100k	vs. severe disease
All ages	1,302,912 18.2%	5,634,634 78.7%	214 16.4	301 5.3	**67.5%**
<50	1,116,834 23.3%	3,501,118 73.0%	43 3.9	11 0.3	**91.8%**
>50	186,078 7.9%	2,133,516 90.4%	171 91.9	290 13.6	**85.2%**

Illustrative Toy Example (Tweet by Srini)

Source: @srinivas_venkat

Old unvaccinated cases: 100	Old vaccinated cases: 20
Old unvaccinated population: 200	Old vaccinated population: 400
Old unvaccinated attack rate: 50%	Old vaccinated attack rate: 5%

$VE_{old} = (1-5/50)*100 = 90\%$



Total unvaccinated cases: 130
Total unvaccinated population: 500
Total unvaccinated attack rate: 26%

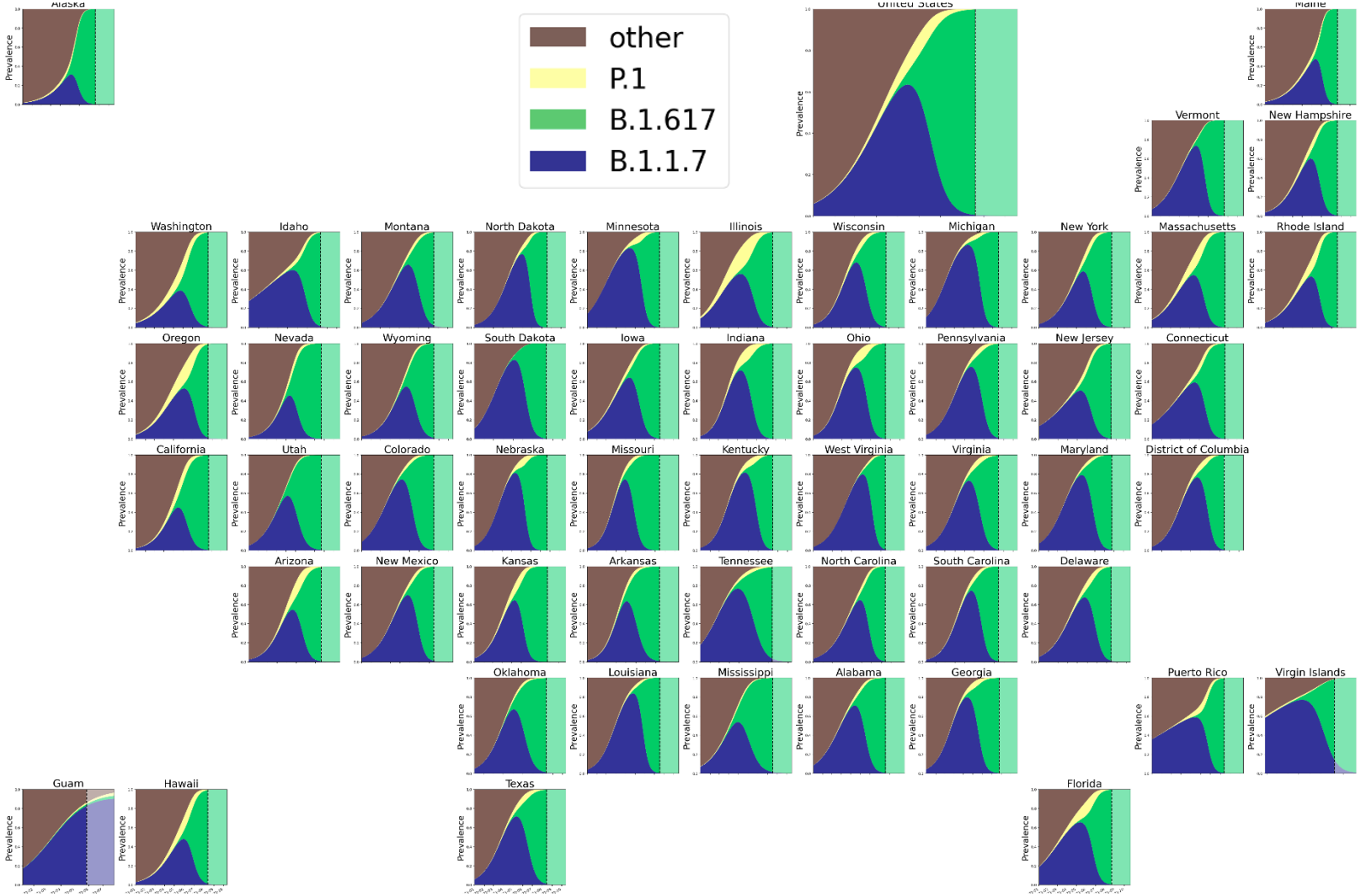
$VE_{total} = (1-4.2/26)*100 = 83.8\%$

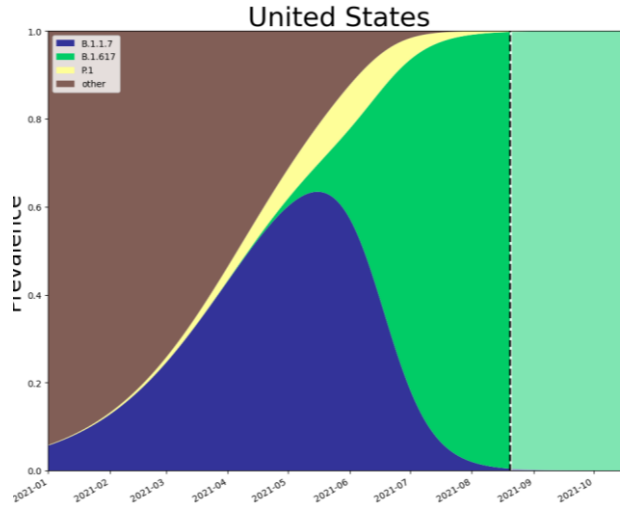
Total vaccinated cases: 21
Total vaccinated population: 500
Total vaccinated attack rate: 4.2%

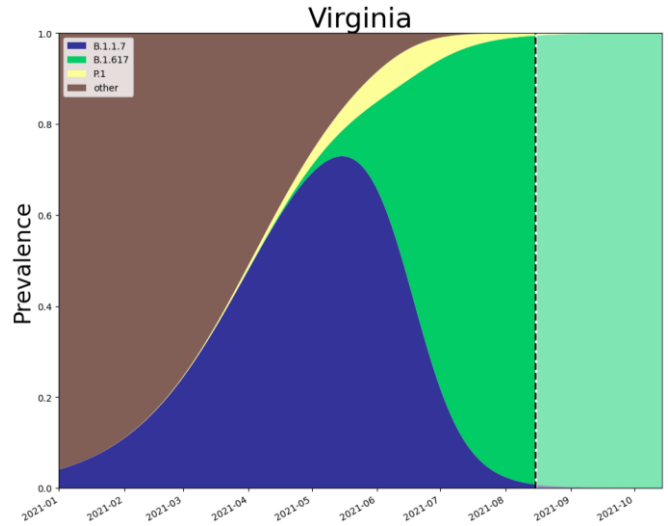
Young unvaccinated cases: 30	Young vaccinated cases: 1
Young unvaccinated population: 300	Young vaccinated population: 100
Young unvaccinated attack rate: 10%	Young vaccinated attack rate: 1%

$VE_{young} = (1-1/10)*100 = 90\%$

Variant of Concern Trajectories

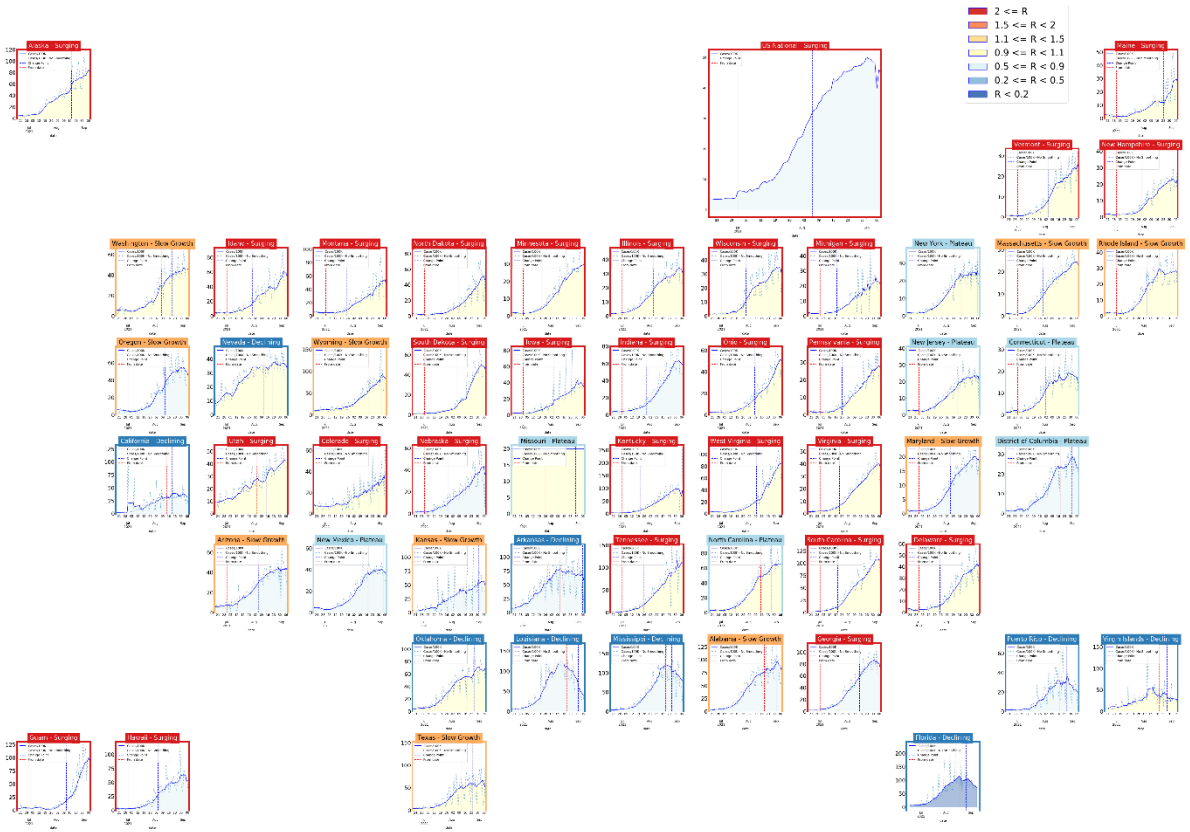






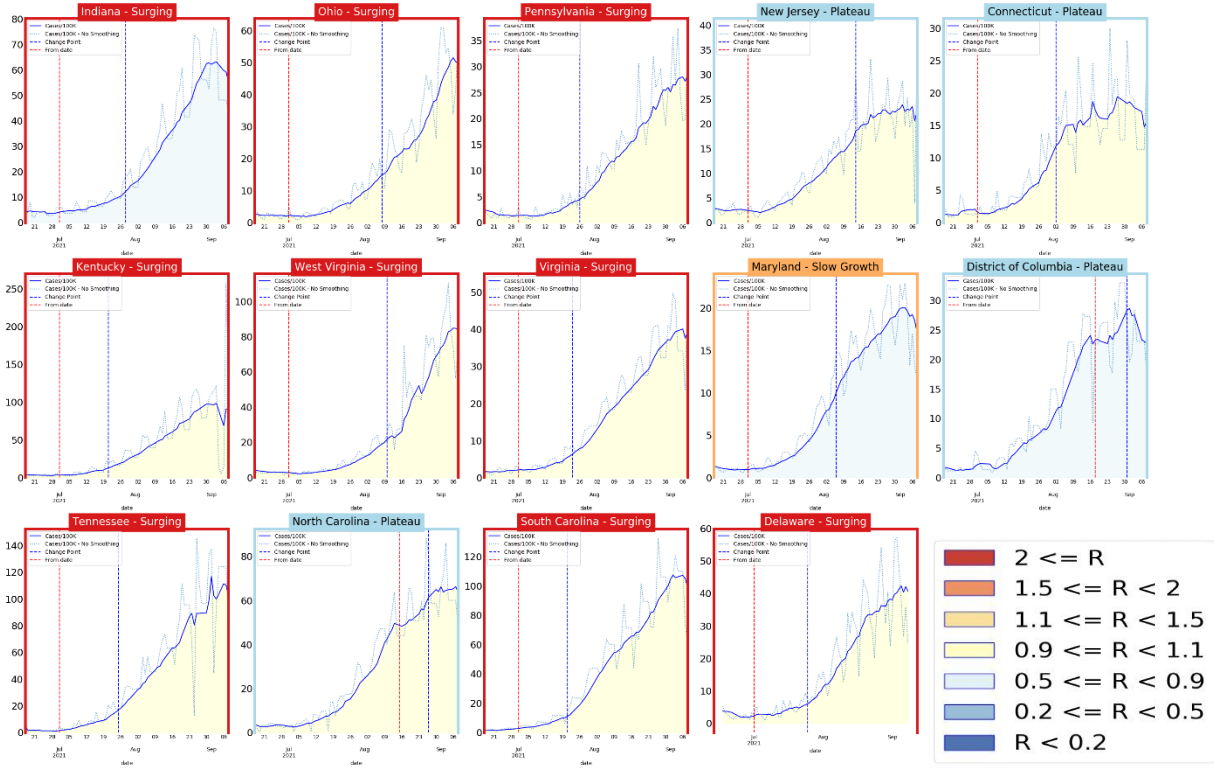
Other State Comparisons

Trajectories of States



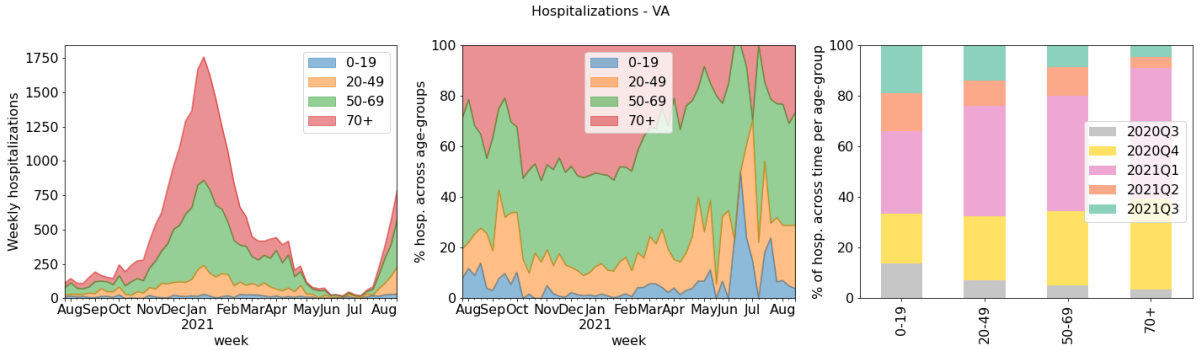
- Most of the country remains in Surge, but many states have are now in decline (9) or are plateaued (3)
- Case rates remain very high, but nationally growth has plateaued

Virginia and her neighbors



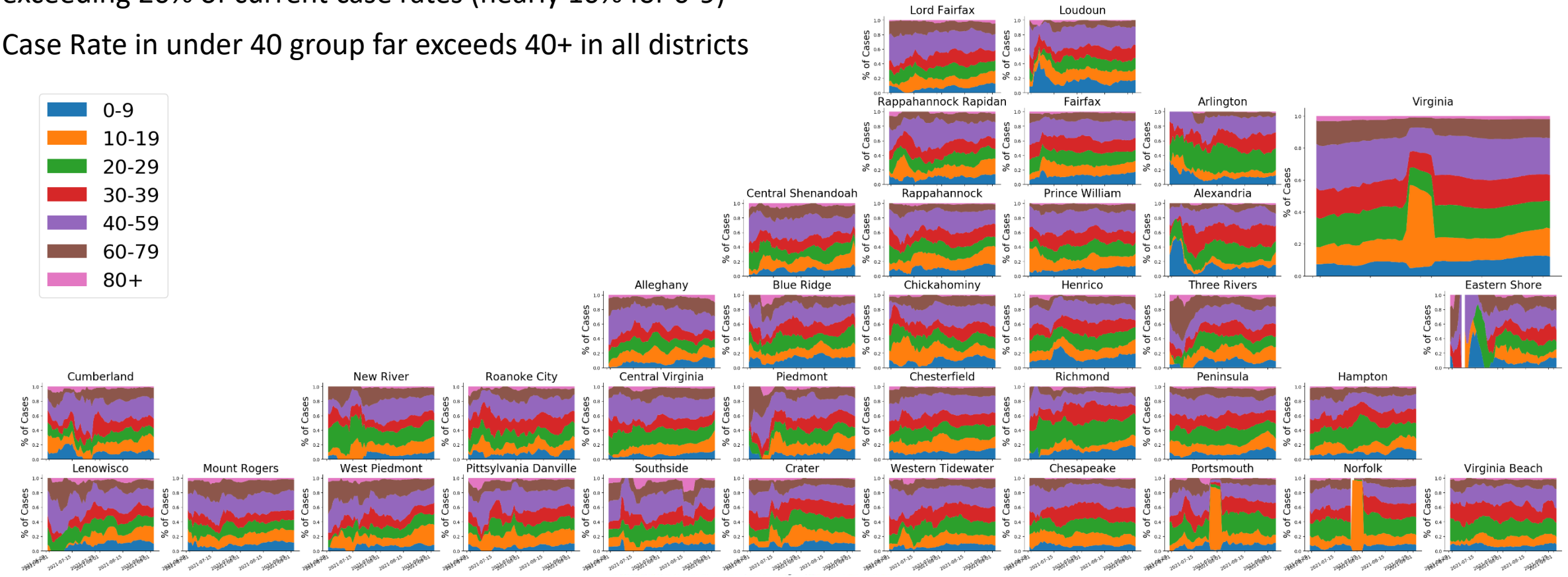
- VA and many neighbors continue to surge but most show signs of slowing, several states have plateaued
- Most remain at very high case rates

Age-Specific Case Rates



Case Rates (per 100K) by Age Groups

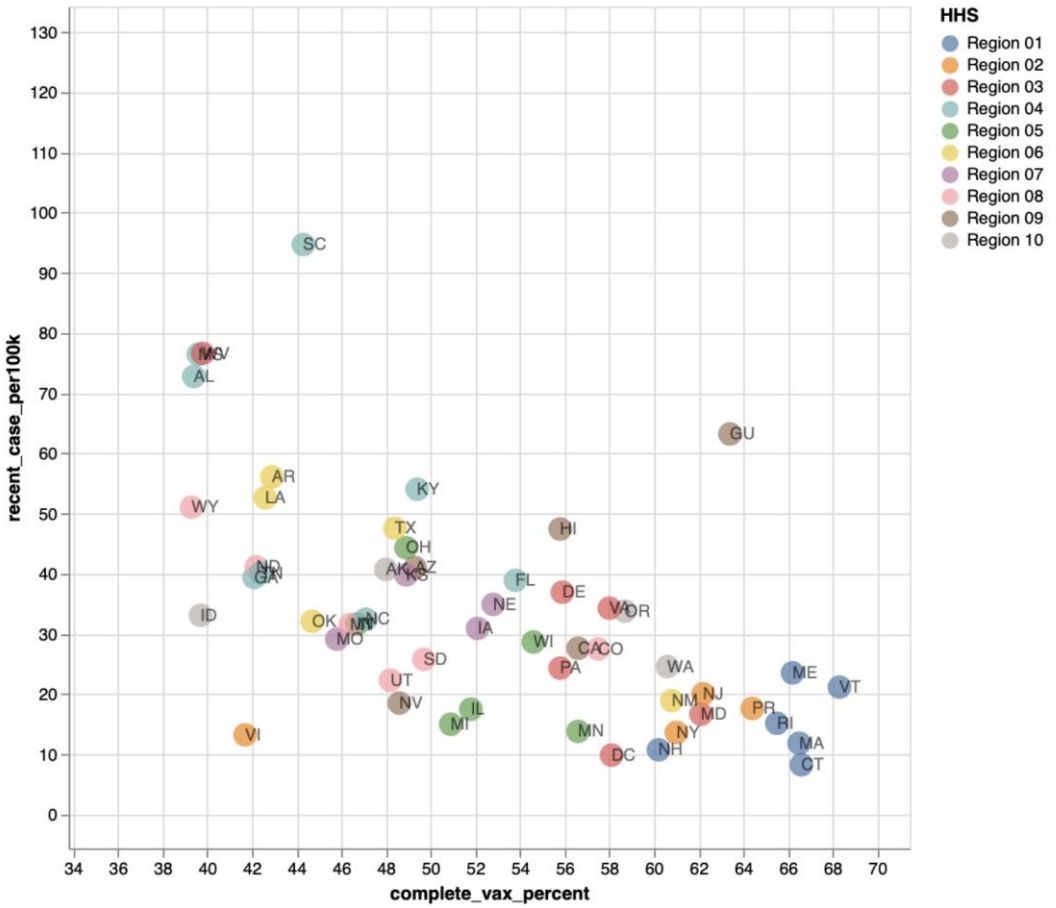
- Rapid growth in many regions in the 0-19 age range, many exceeding 20% of current case rates (nearly 10% for 0-9)
- Case Rate in under 40 group far exceeds 40+ in all districts



Recent Cases Correlate with Vax Coverage

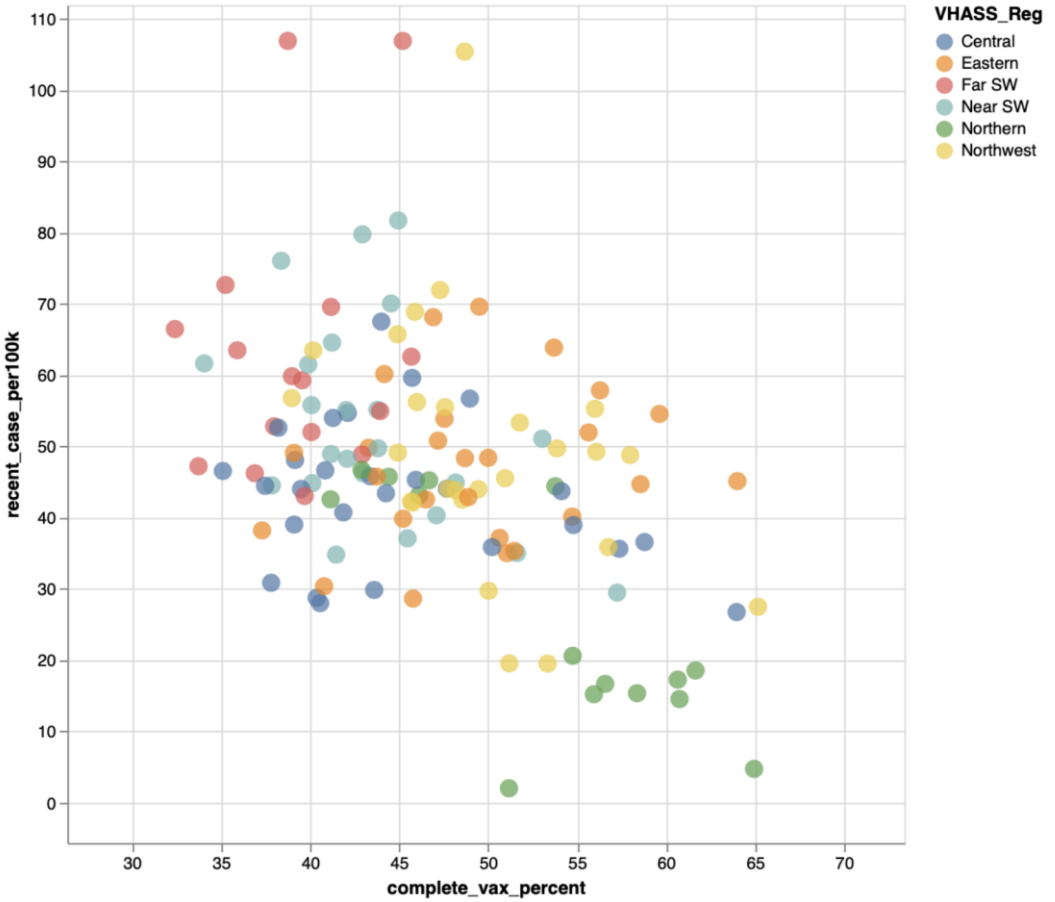
Mean cases per 100K vs. vaccine coverage

- 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



Zip code level weekly Case Rate (per 100K)

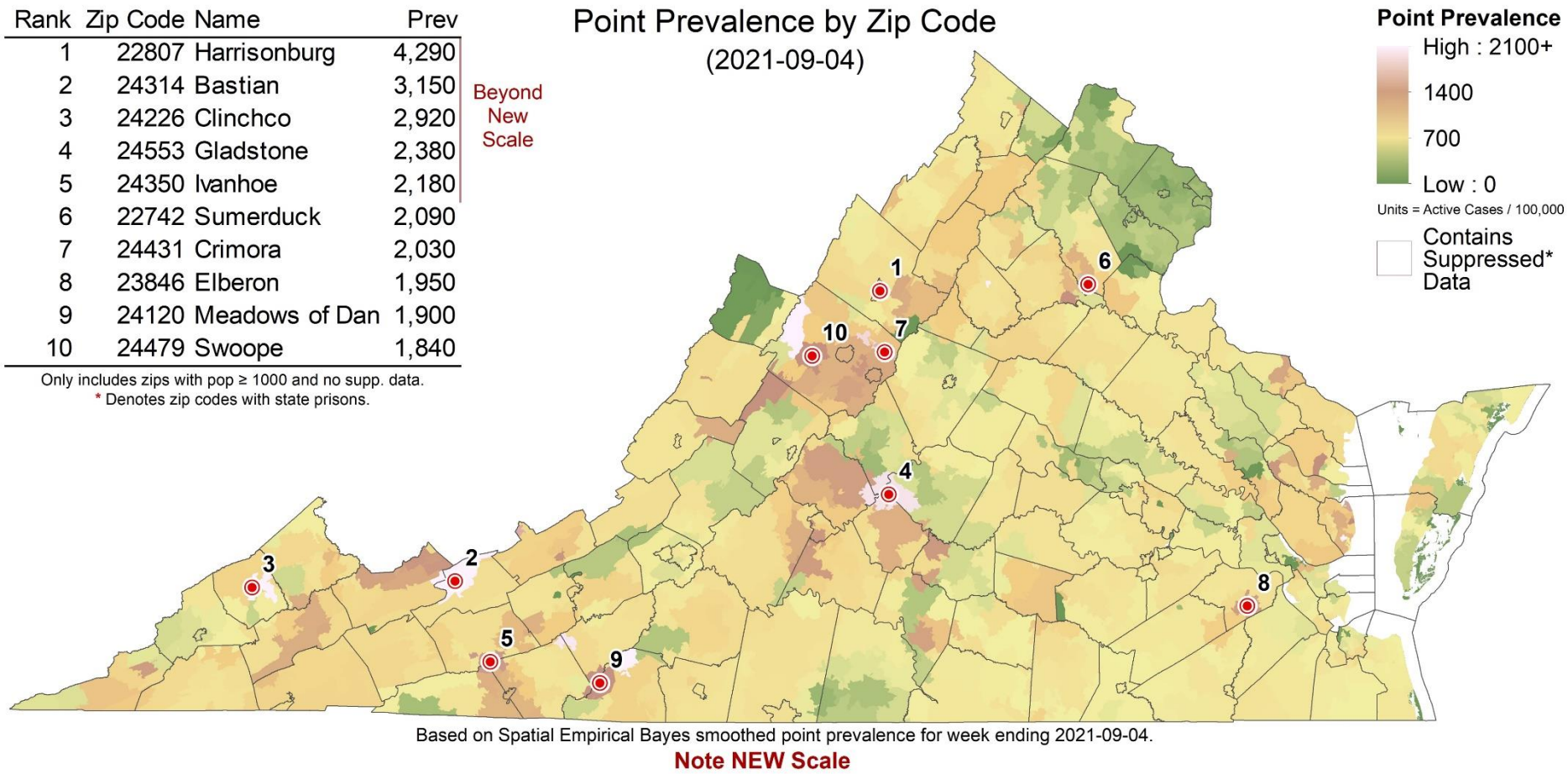
Case Rates in the last week by zip code

- Color scaled adjusted to accommodate the very high prevalence levels this week
- 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	22807	Harrisonburg	4,290
2	24314	Bastian	3,150
3	24226	Clinchco	2,920
4	24553	Gladstone	2,380
5	24350	Ivanhoe	2,180
6	22742	Sumerduck	2,090
7	24431	Crimora	2,030
8	23846	Elberon	1,950
9	24120	Meadows of Dan	1,900
10	24479	Swoope	1,840

Beyond New Scale

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 2021-09-04.

Note NEW Scale

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Risk of Exposure by Group Size

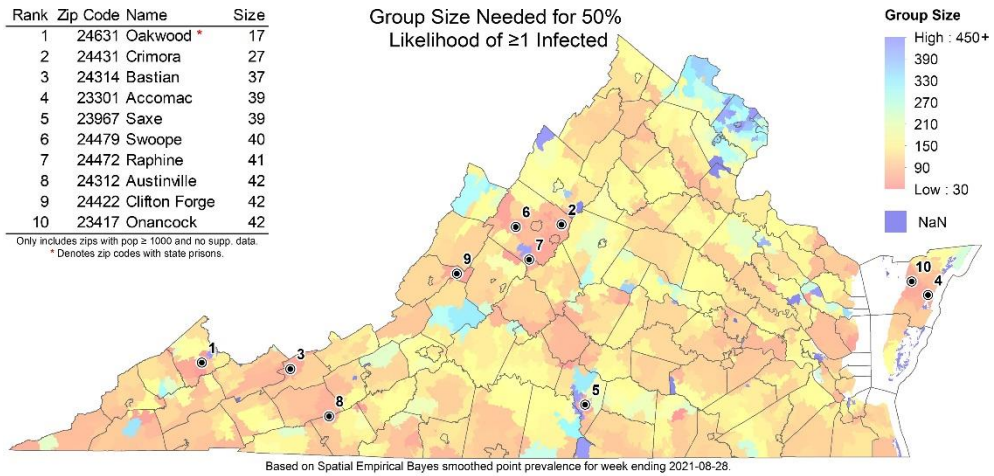
Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25)

- **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 16 in Harrisonburg, there is a 50% chance someone will be infected)

From Last Week

Rank	Zip Code	Name	Size
1	24631	Oakwood *	17
2	24431	Crimora	27
3	24314	Bastian	37
4	23301	Accomac	39
5	23967	Saxe	39
6	24479	Swoope	40
7	24472	Raphine	41
8	24312	Austinville	42
9	24422	Clifton Forge	42
10	23417	Onancock	42

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

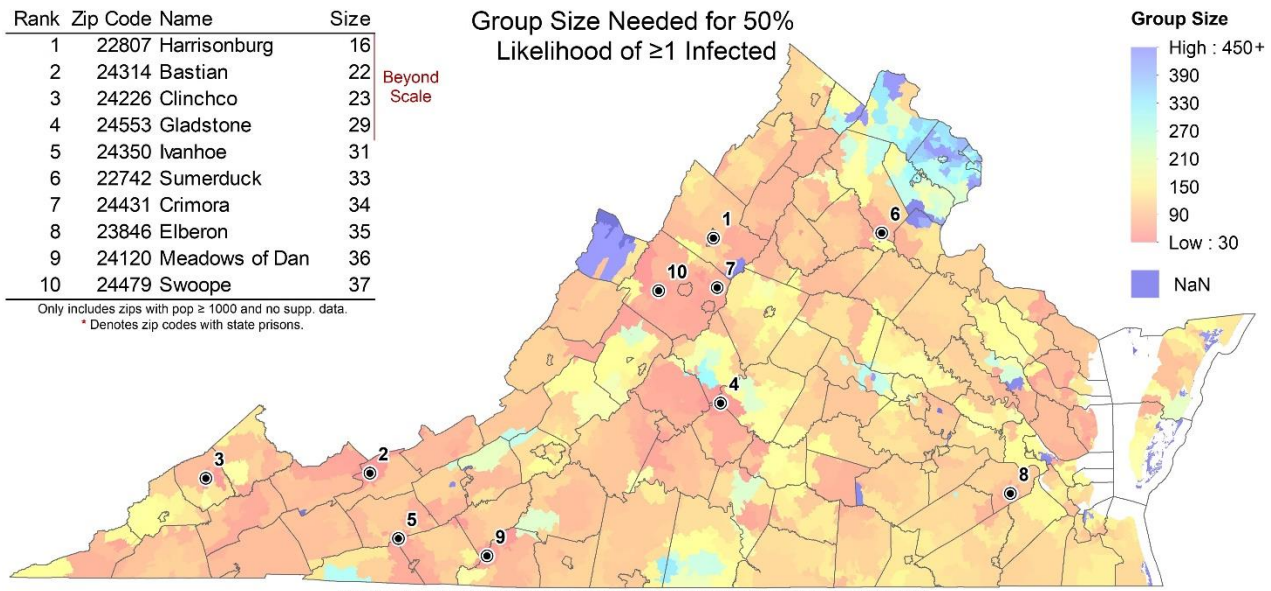


Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-08-28.

Rank	Zip Code	Name	Size
1	22807	Harrisonburg	16
2	24314	Bastian	22
3	24226	Clinchco	23
4	24553	Gladstone	29
5	24350	Ivanhoe	31
6	22742	Sumerduck	33
7	24431	Crimora	34
8	23846	Elberon	35
9	24120	Meadows of Dan	36
10	24479	Swoope	37

Beyond Scale

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 2021-09-04.

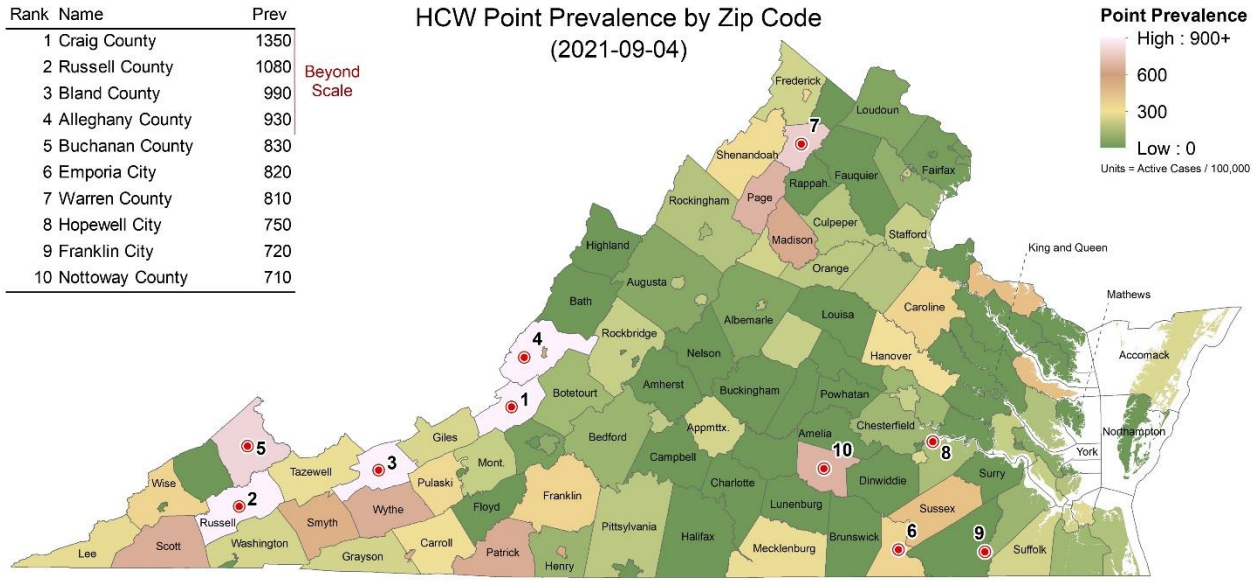
HCW Prevalence

- **HCW prevalence**: Case rate among health care workers (HCW) in the last week using patient facing health care workers as the denominator
  - Clusters of high HCW point prevalence in far southwest (Wise & Dickinson Counties) and south of Richmond (Lunenburg and Prince Edward to Surry Counties)
- **HCW Ratio**: HCW Prevalence / Total Case Prevalence
  - (blue = higher case rate among public, red = higher case rate among HCW)

HCW Prevalence

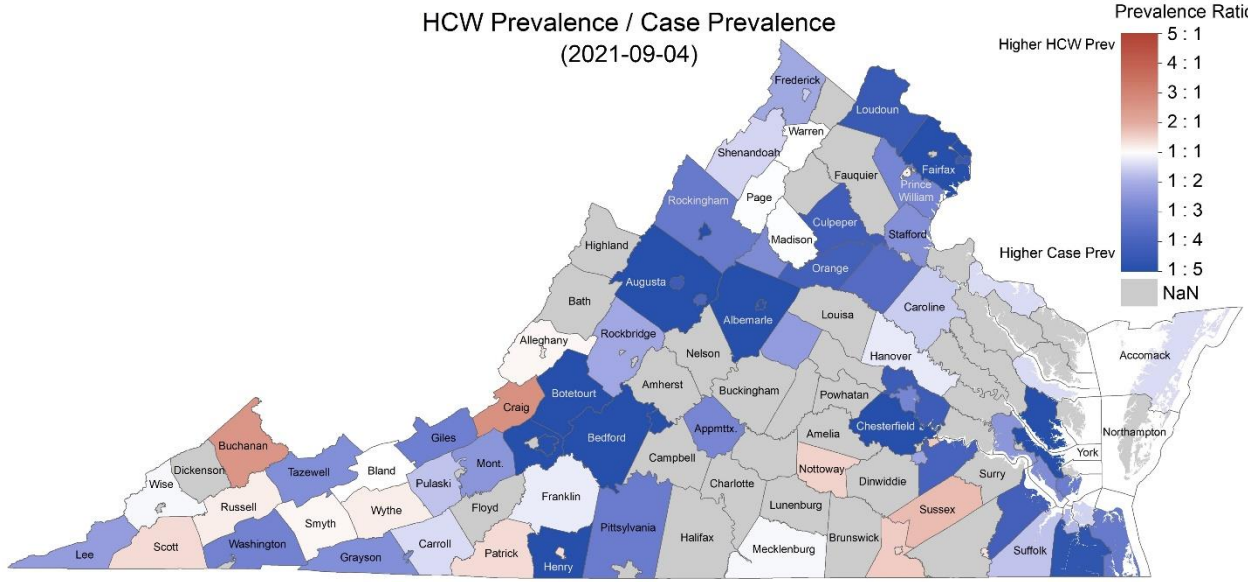
Rank	Name	Prev
1	Craig County	1350
2	Russell County	1080
3	Bland County	990
4	Alleghany County	930
5	Buchanan County	830
6	Emporia City	820
7	Warren County	810
8	Hopewell City	750
9	Franklin City	720
10	Nottoway County	710

Beyond Scale



Note: Scale differs from general public prevalence maps.

HCW to Public Prevalence Ratio



Current Hot-Spots

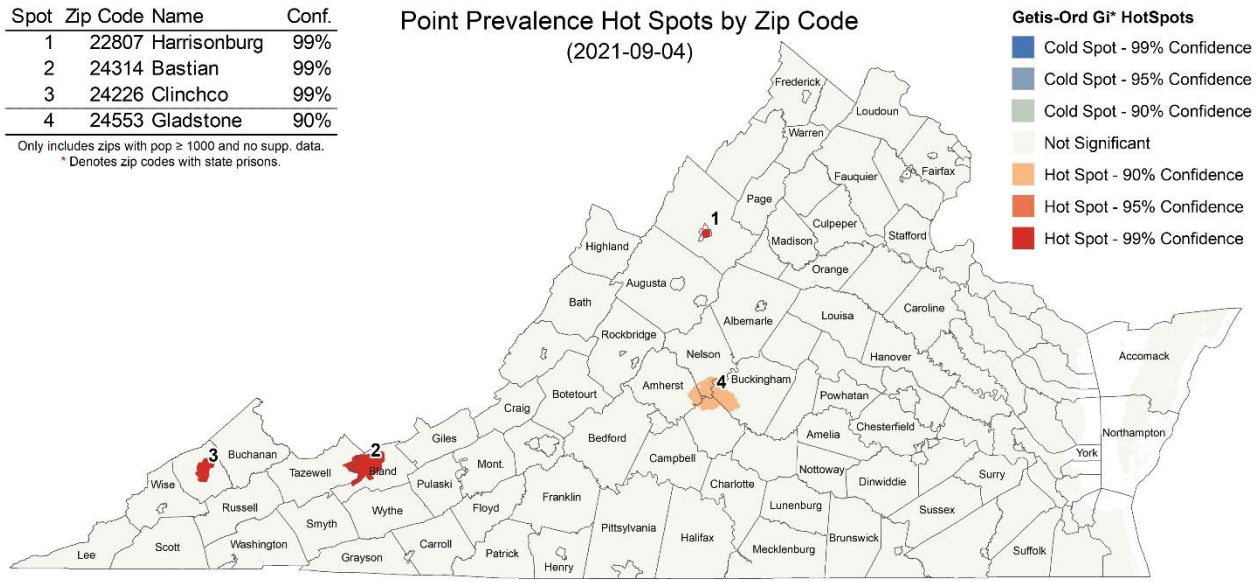
Case rates that are significantly different from neighboring areas or model projections

- **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

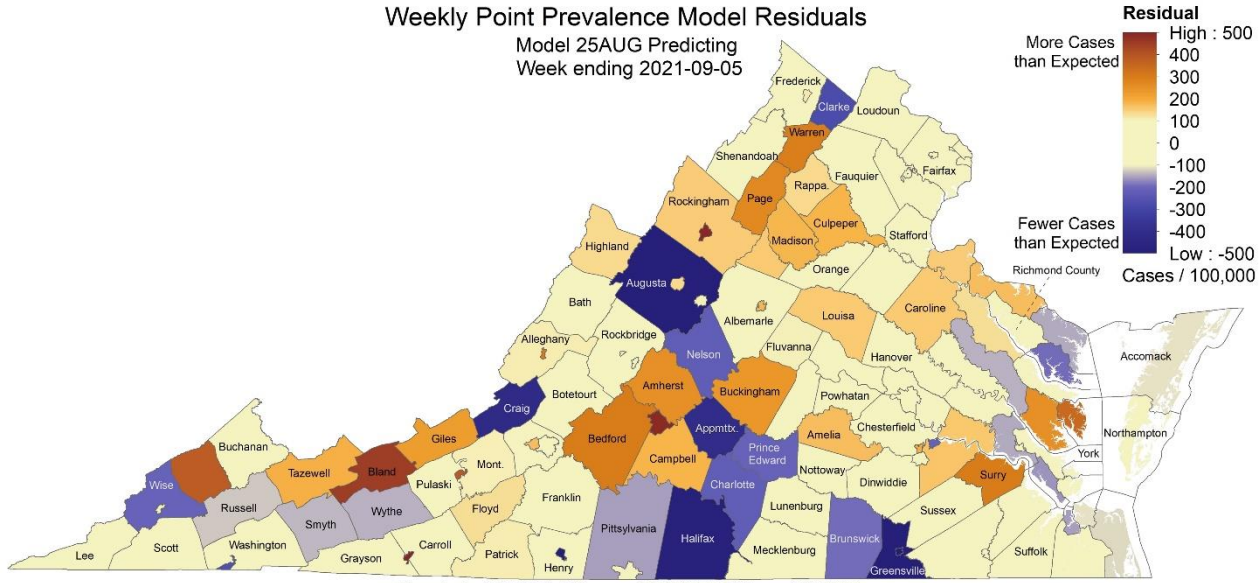
Spot	Zip Code	Name	Conf.
1	22807	Harrisonburg	99%
2	24314	Bastian	99%
3	24226	Clinchco	99%
4	24553	Gladstone	90%

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 2021-09-04.

Clustered Temporal Hotspots



Moran's I = 0.074571, Z-Score = 3.648637, P-Value = 0.000264
Residual Autocorrelation DETECTED

Model Update – Adaptive Fitting

Adaptive Fitting Approach

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

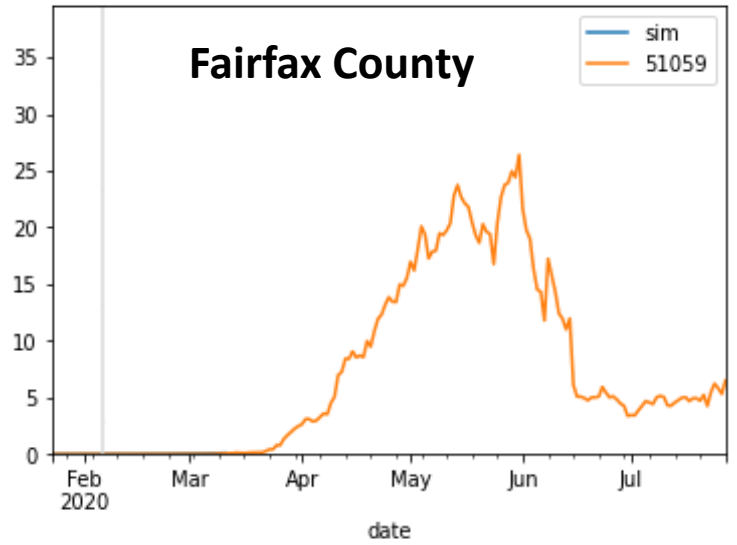
- Allows history to be precisely captured, and used to guide bounds on projections

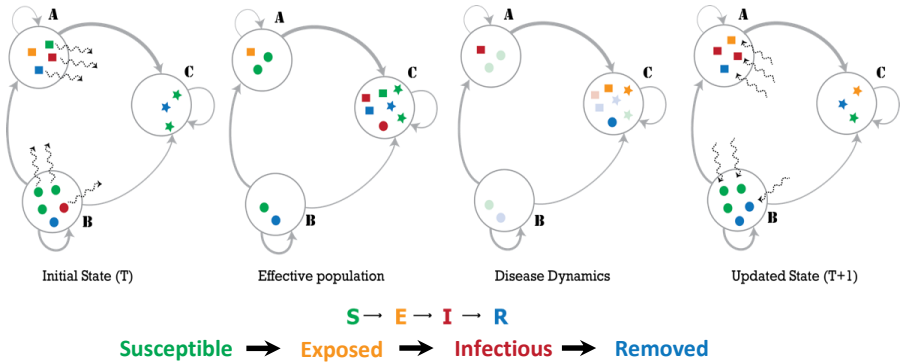
Model: An alternative use of the same meta-population model, PatchSim

- 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:

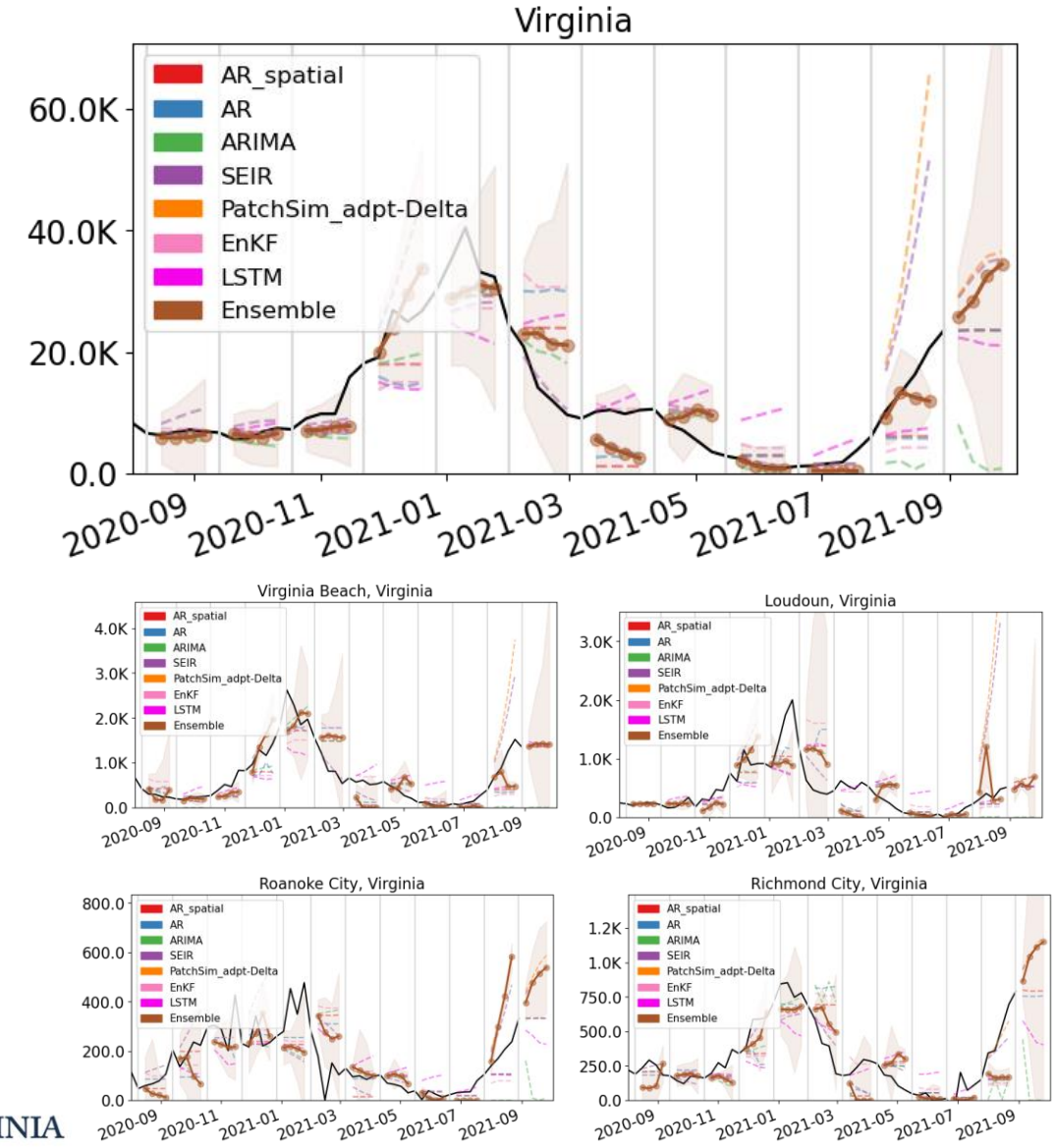
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

<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.



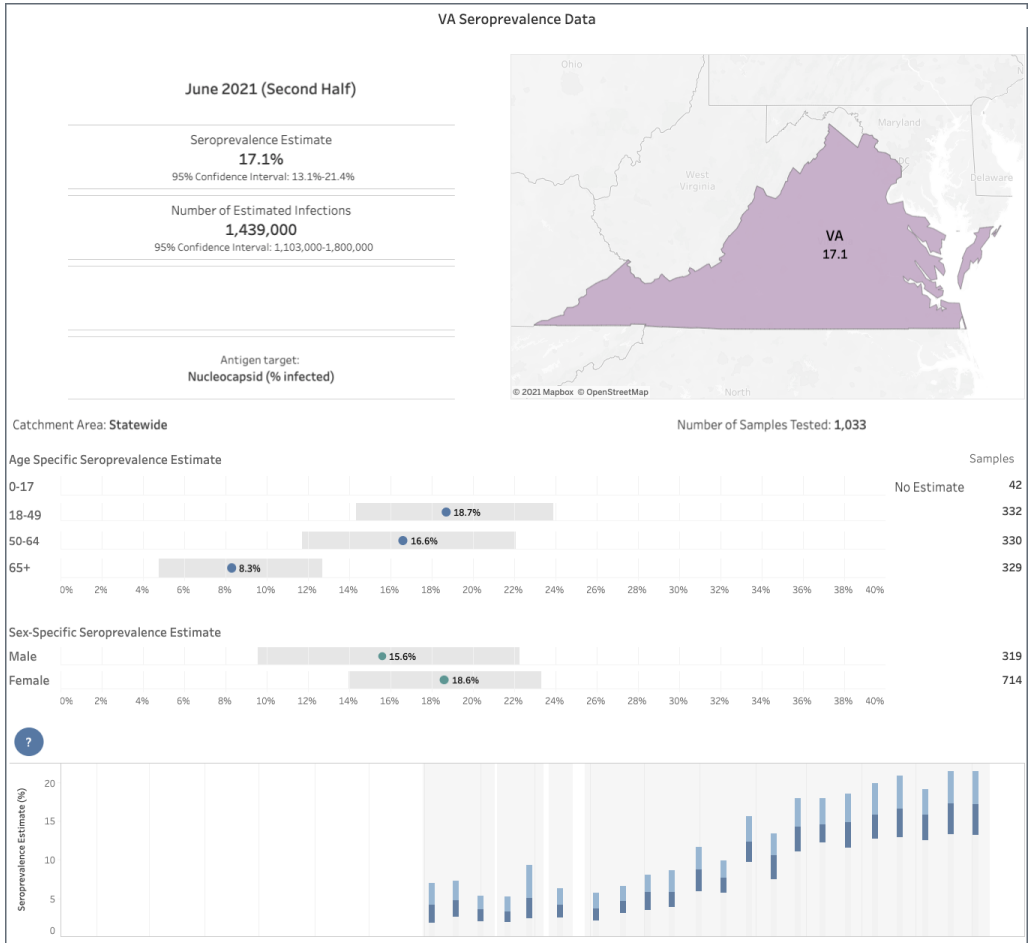
Seroprevalence updates to model design

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

- CDC Nationwide Commercial Laboratory Seroprevalence Survey

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

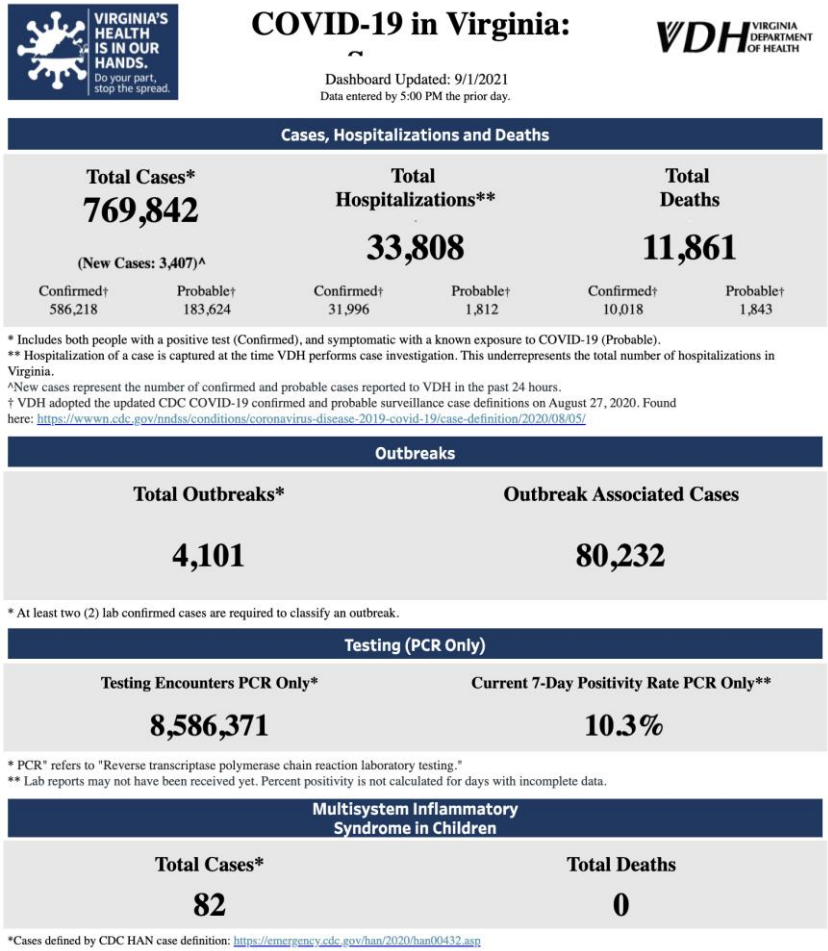
- Thus for 2x there are 2 total infections in the population for every confirmed case recently
- This measure now fully tracks the estimated ascertainment over time
- Uncertainty design has been shifted to these bounds (previously higher ascertainments as was consistent earlier in the pandemic were being 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: 9/1/2021
Data entered by 5:00 PM the prior day.

Cases, Hospitalizations and Deaths

Total Cases*		Total Hospitalizations**		Total Deaths	
769,842		33,808		11,861	
(New Cases: 3,407)^					
Confirmed†	Probable†	Confirmed†	Probable†	Confirmed†	Probable†
586,218	183,624	31,996	1,812	10,018	1,843

* 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
4,101	80,232

* 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**
8,586,371	10.3%

* 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
82	0

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

Accessed 10:45am September 8, 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
- **Waning Immunity**: Mean of one year protection (rate of 0.0027) similar to Pfizer study
- **Projection Scenarios**:
  - **Adaptive:** Control remains as is currently experienced into the future with assumption that Delta remains as the majority strain
  - **Adaptive-SeptSurge:** Following Labor Day 2021, transmission rates return to the median level from Sept-Nov of 2020 with a 60% boost over ancestral strain that dominated then.
  - **Adaptive-Surge Control:** Starting in one week behaviors and mitigation efforts ramp up over a 2-week period culminating in a 25% reduction in transmission
  - **Adaptive-Fall:** Control remains as is currently experienced into the future, with an increase in transmission that is 60% stronger than the median experienced October 2020 through February 2021 starting on Nov 1st

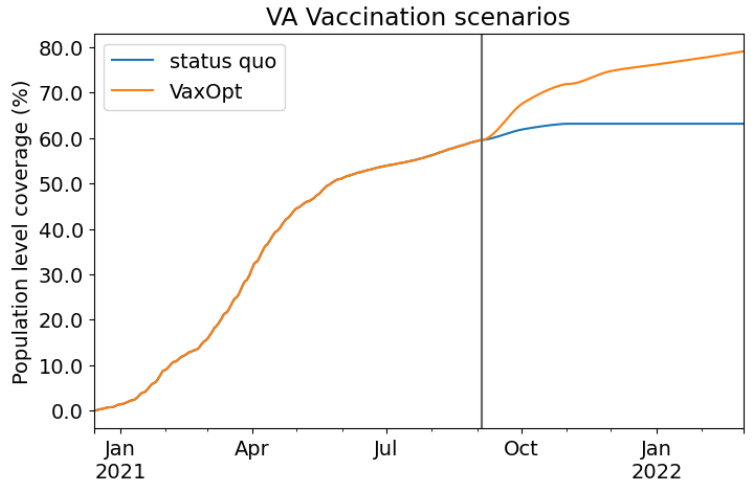
Scenarios – Vaccination Conditions

Vaccine Characteristics

- **Pfizer/Moderna**: 50% after first dose, 95% after second dose (3.5 week gap) **J & J** : 67% efficacy after first 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 ~80% adults, 65% of population) reached by end of October.
- **Optimistic (VaxOpt):** Expand VA mean acceptance to include ”probably not” (~85% adults) with addition of childhood (5-11 yo) rollout starting in Nov 1st. This follows the same rates as observed of adolescents and results in a net increase of ~10% of population by end of February. Additionally, all counties guaranteed to reach 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)



Monthly first doses

Date	status quo	VaxOpt
2020-12-31	108.9K	108.9K
2021-01-31	753.7K	753.7K
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	5.0M	5.1M
2021-09-30	5.5M	5.8M
2021-10-31	5.8M	6.1M
2021-11-30	5.8M	6.4M
2021-12-31	5.8M	6.5M
2022-01-31	5.8M	6.6M
2022-02-28	5.8M	6.7M
2022-03-31	5.8M	6.7M

Cumulative

Date	status quo	VaxOpt
2020-12-31	108.9K	108.9K
2021-01-31	644.8K	644.8K
2021-02-28	557.6K	557.6K
2021-03-31	1.3M	1.3M
2021-04-30	1.2M	1.2M
2021-05-31	573.6K	573.6K
2021-06-30	242.1K	242.1K
2021-07-31	196.7K	196.7K
2021-08-31	261.0K	266.1K
2021-09-30	483.5K	721.8K
2021-10-31	237.0K	351.3K
2021-11-30	0.0	239.9K
2021-12-31	0.0	124.8K
2022-01-31	0.0	122.6K
2022-02-28	0.0	122.4K
2022-03-31	0.0	4.6K

Projection Scenarios – Combined Conditions

Name	Txm Controls	Vax	Description
Adaptive	C	SQ	Likely trajectory based on conditions remaining similar to the current experience
Adaptive-VaxOpt	C	VO	Vaccination through October reaches an optimistically high level of expanded coverage (85%)
Adaptive-Fall	Fall	SQ	Same as Adaptive, with increased transmissibility driven by seasonality and/or another variant starting Nov 1st
Adaptive-Fall-VaxOpt	Fall	VO	Optimistically expand vaccination with increased transmissibility driven by seasonality and/or another variant starting Nov 1st
Adaptive-SurgeControl	25%	SQ	Transmission rates in the next month reduced through increased control from non-pharmaceutical interventions, with status quo vax and Delta
Adaptive-SeptSurge	Sept	SQ	Transmission rates return to rates experienced in May 2021 with status quo vaccination and increasing prevalence of Delta

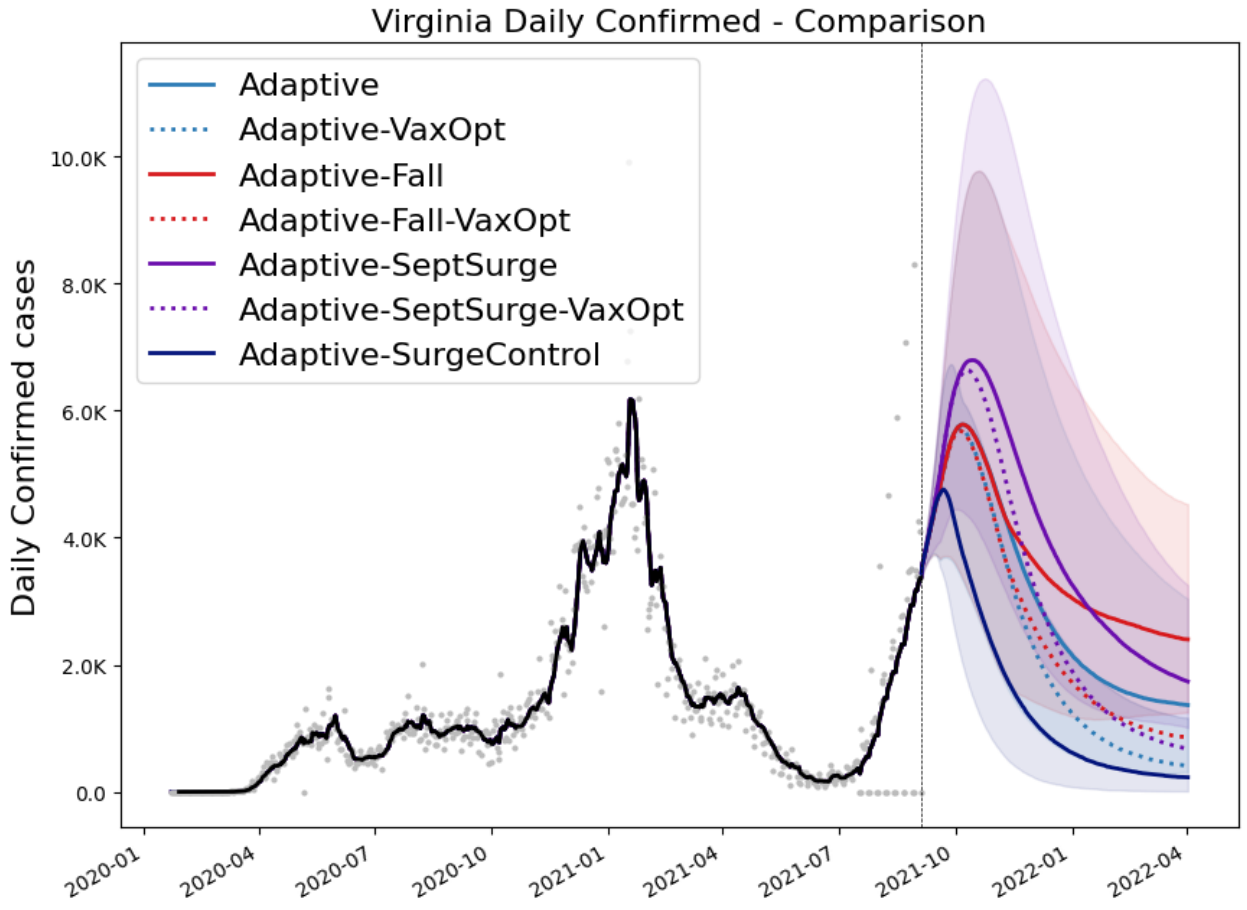
Transmission Controls:
C = Current levels persist into the future
25% = Transmission rates are reduced by 25% with a gradual introduction, concluding in 4 weeks
Fall = Current levels until Nov 1st, then the median level from Oct-Feb of last year with 60% variant boost
Sept = Transmission rates return to median of Sept-Nov 2020 with 60% boost following Labor Day

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

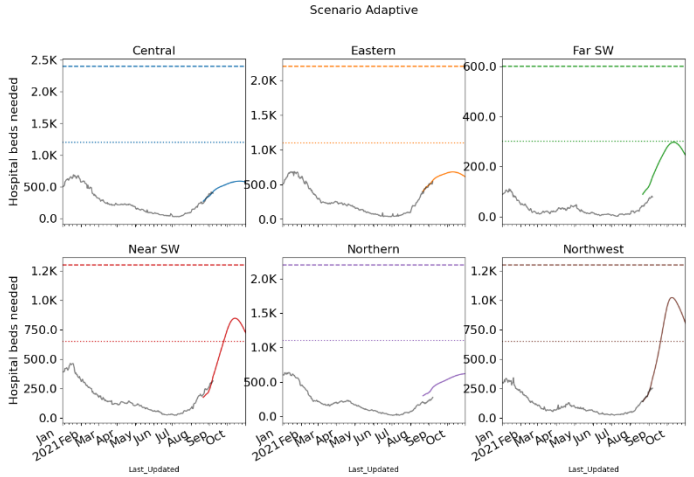
Model Results

Outcome Projections

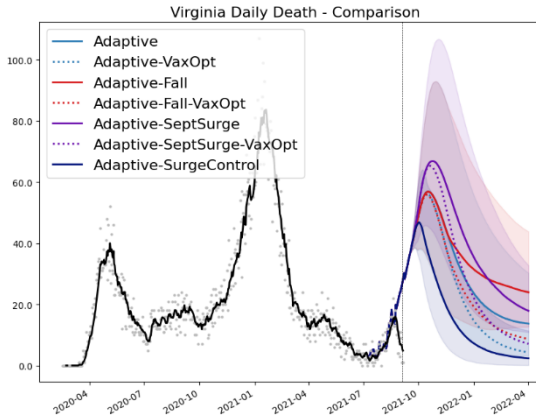
Confirmed cases



Estimated Hospital Occupancy

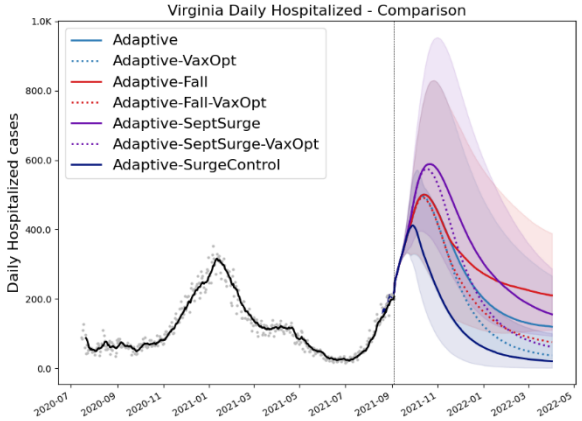


Daily Deaths



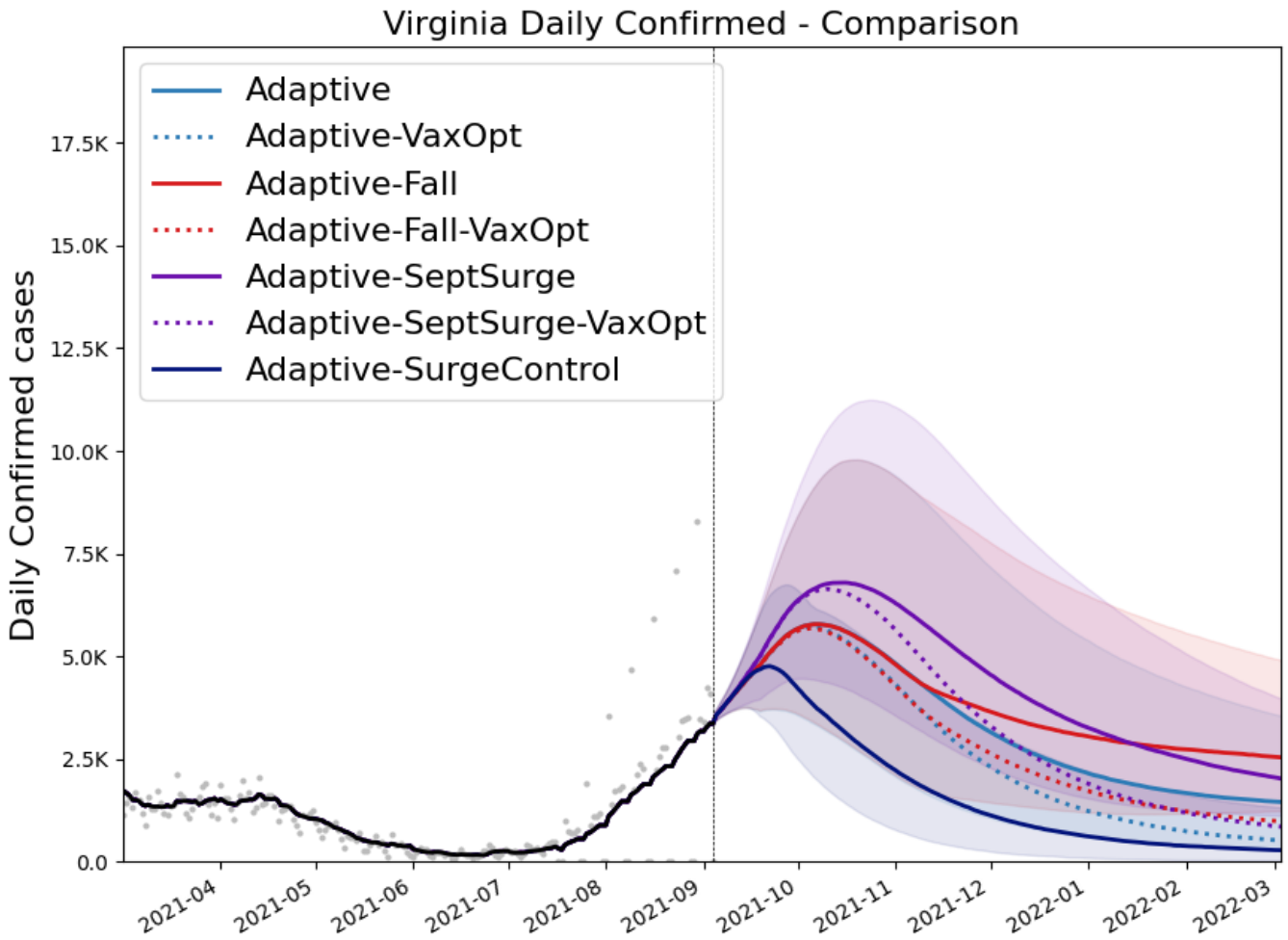
Death ground truth from VDH "Event Date" data, most recent dates are not complete

Daily Hospitalized

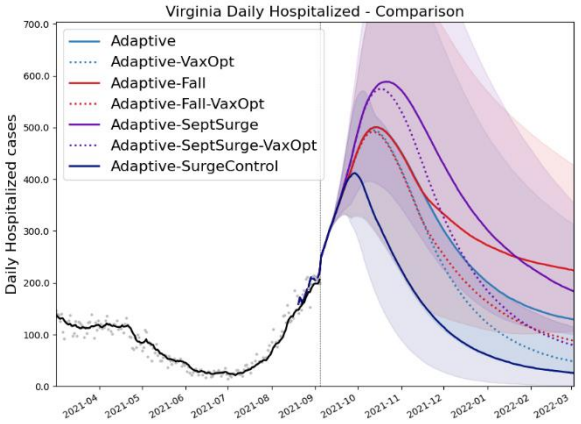


Outcome Projections – Closer Look

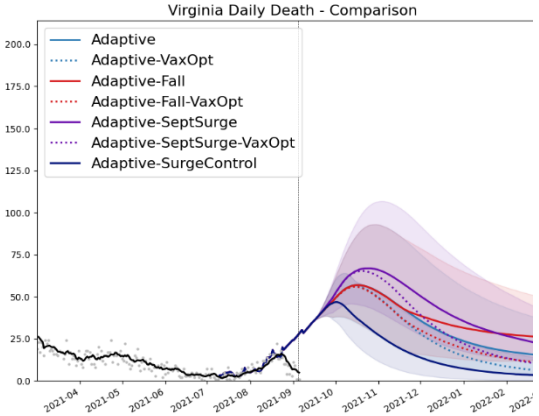
Confirmed cases



Daily Hospitalized



Daily Deaths



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

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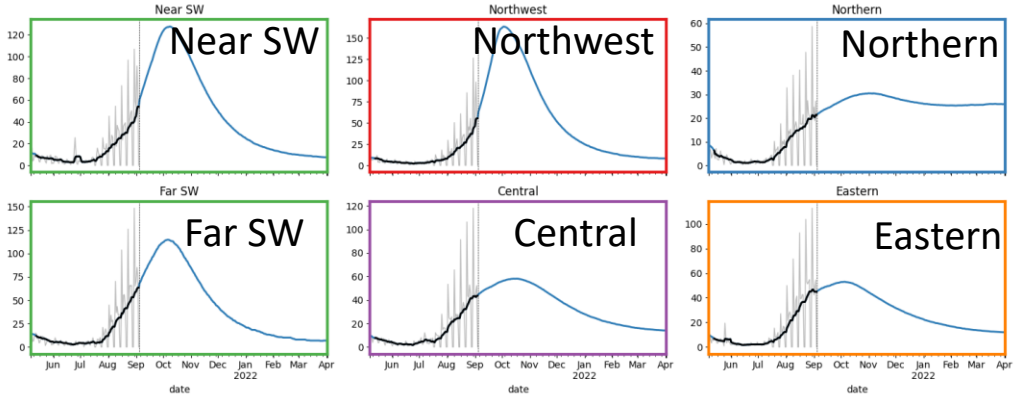
District Level Projections: Adaptive

Projections by Region

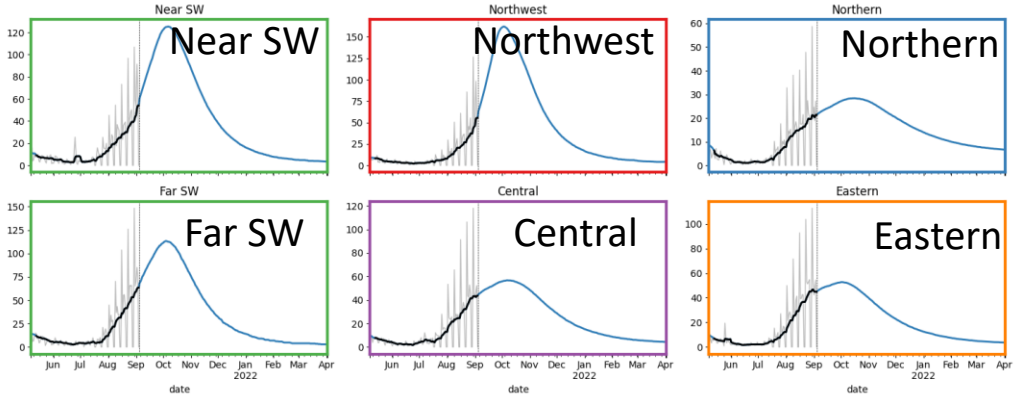


Projections by District

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

District Level Projections: Adaptive-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

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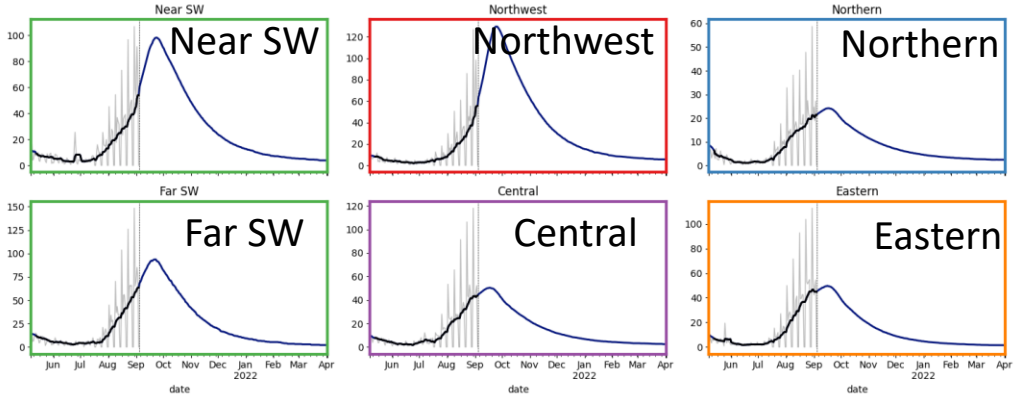
District Level Projections: SurgeControl

Projections by Region

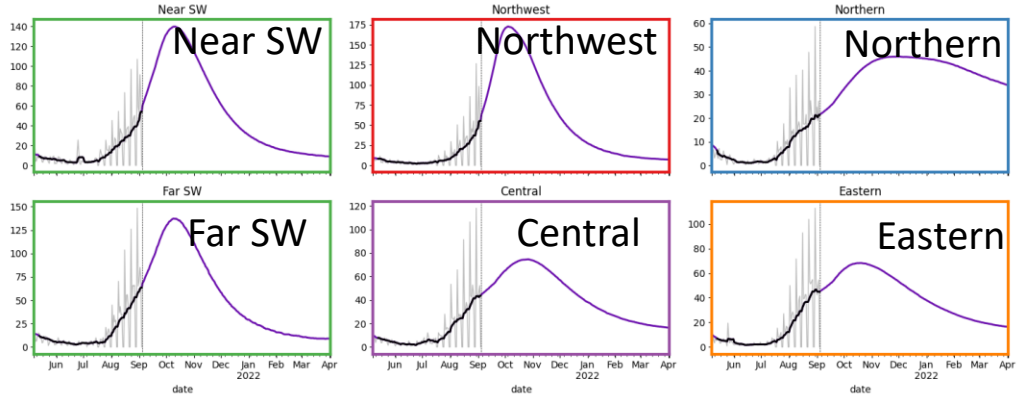


Projections by District

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

District Level Projections: SeptSurge

Projections by Region

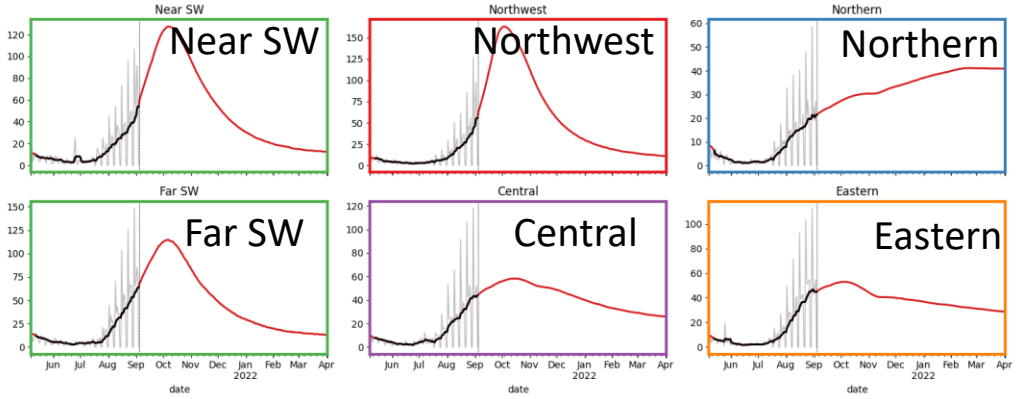


Projections by District

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

District Level Projections: Adaptive-Fall

Projections by Region

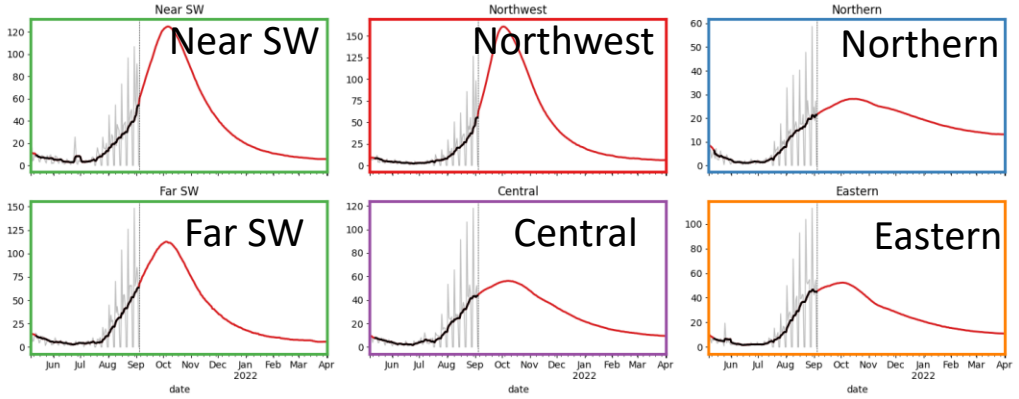


Projections by District

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

District Level Projections: Adaptive-Fall-VaxOpt

Projections by Region



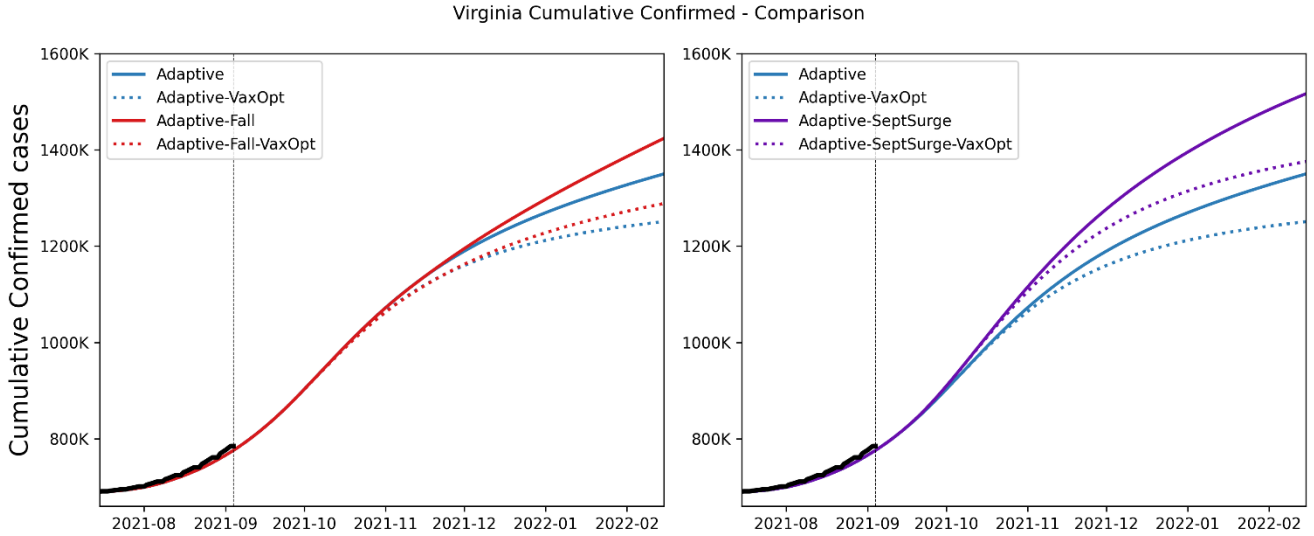
Projections by District

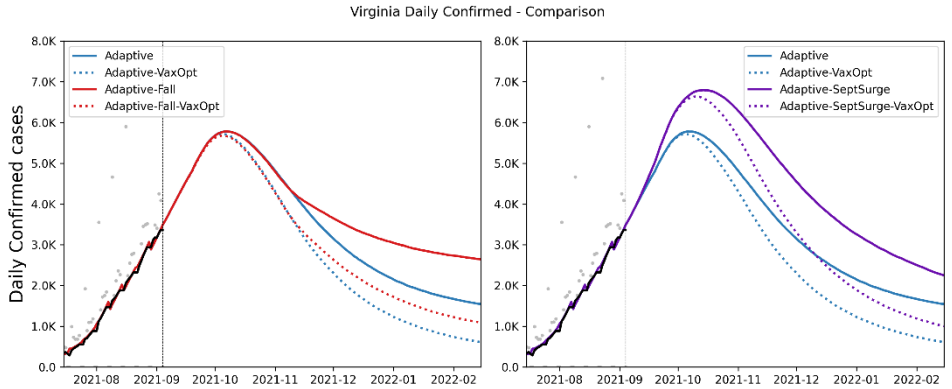
Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

Impact of expanded vaccine acceptance

Expanded Vax coverage with higher adult coverage & 5-11 year olds in Nov

- Even if transmission rates decline after a Delta wave, expanded vax coverage can reduce case counts by ~140K, in addition to providing further resilience to future waves
- A Fall Surge can slow the declining rates following the Delta wave
- Expanded vaccination coverage including children can further curtail the impact of a Fall Surge by up to ~200K cases or dampen the effects of a boosted SeptSurge by ~180K cases





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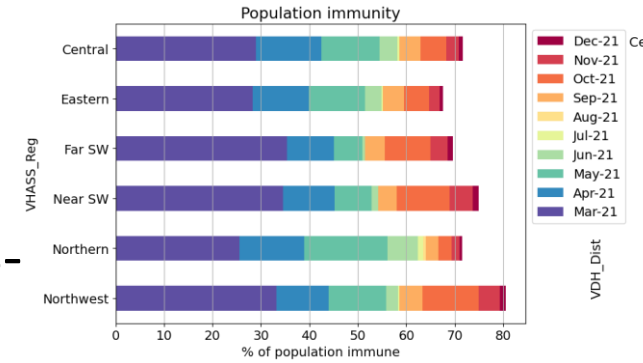
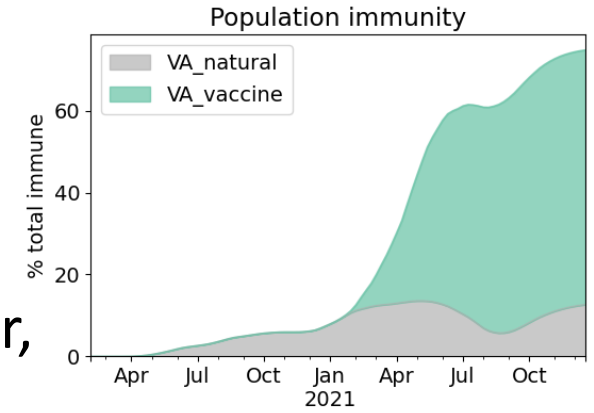
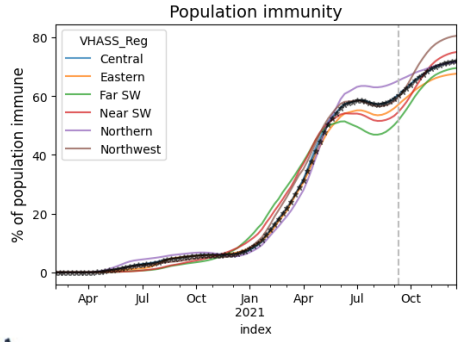
Virginia's Progress on Population Immunity

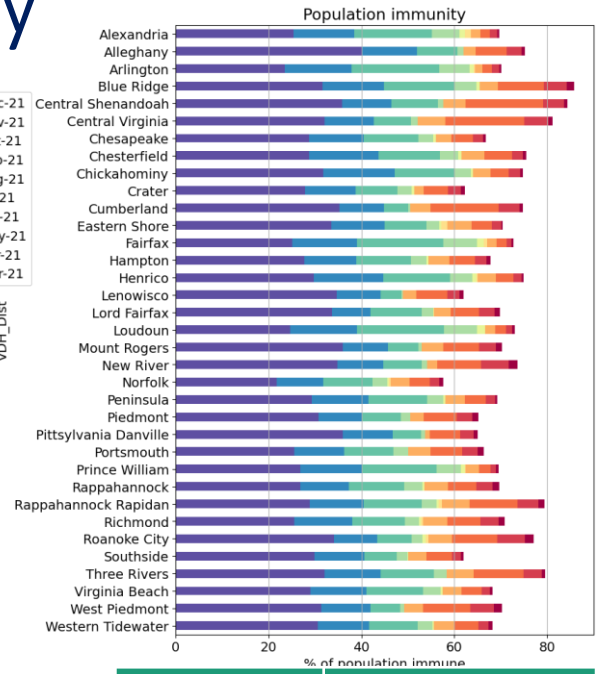
Natural Immunity and Vaccines combine to produce a population level of immunity

- 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	59%
Eastern	56%
Far SW	50%
Near SW	53%
Northern	67%
Northwest	58%
Virginia	59%

* As of Sept 5, 2021 (updated to account for entire population)

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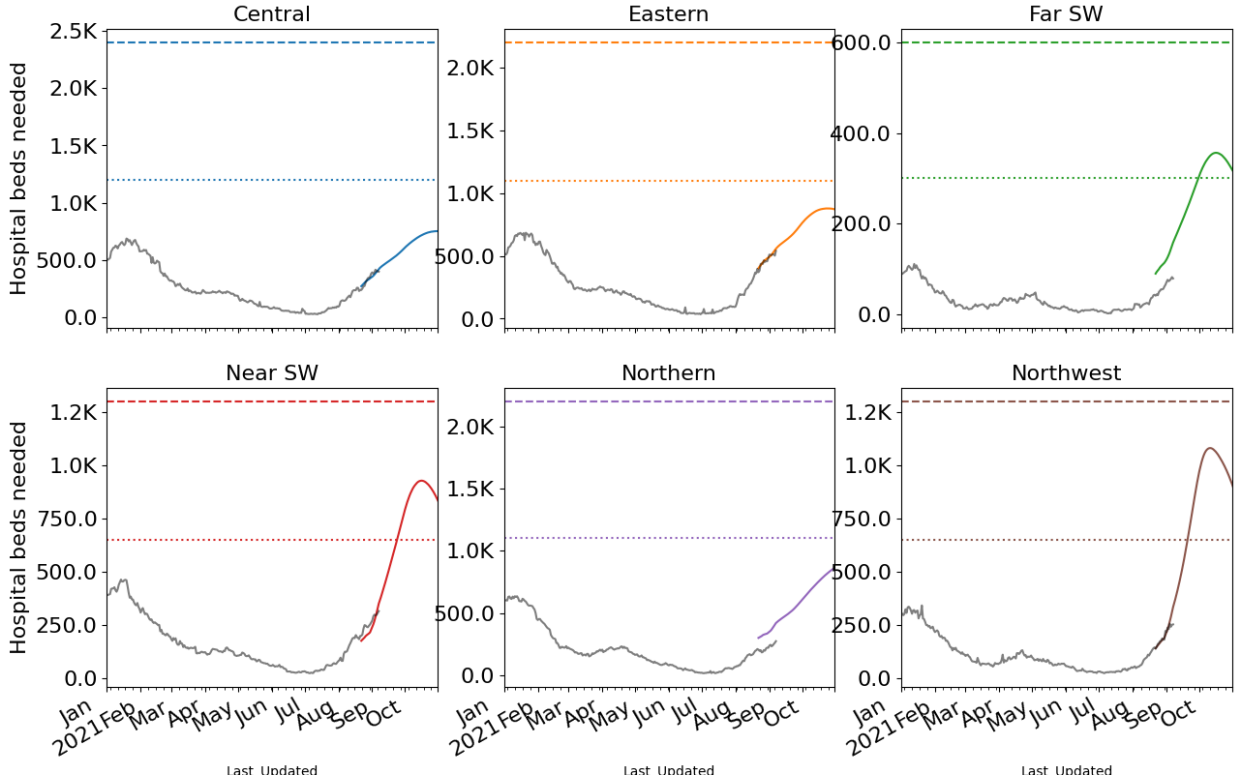
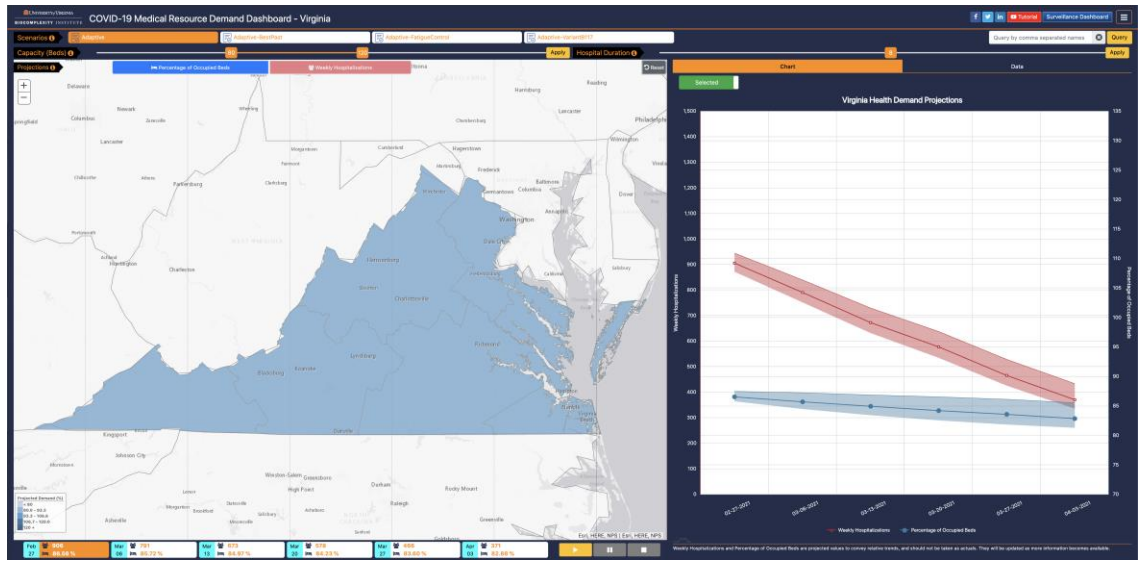
Hospital Demand and Bed Capacity by Region

Capacities* by Region – Adaptive SeptSurge

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





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

Adaptive SeptSurge scenario shows that even with Delta enhanced severity:

- No regions should exceed their surge capacities
- Some regions may exceed 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 though the pace remains steady while US plateaus and some states start to decline; case rates remain very high**
- VA mean weekly incidence flat at 38/100K from 37/100K, US flat to 48/100K (from 48/100K)
- Projections continue to show significant uptick in activity, however, the reduced pace has decreased the overall impact
- Recent updates:
  - Added a SeptSurge based on transmission rates from last year Labor Day to Thanksgiving with variant boosting
  - Added Fall surge scenario to capture potential rebounds and further test immunity from expanded vaccination
  - Updated Optimistic Vaccination to include potential inclusion of 5-11 year olds this Fall

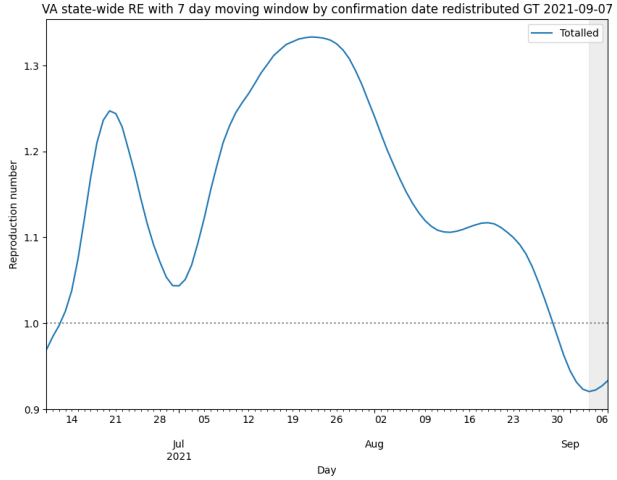
The situation continues to change. Models continue to be updated regularly.

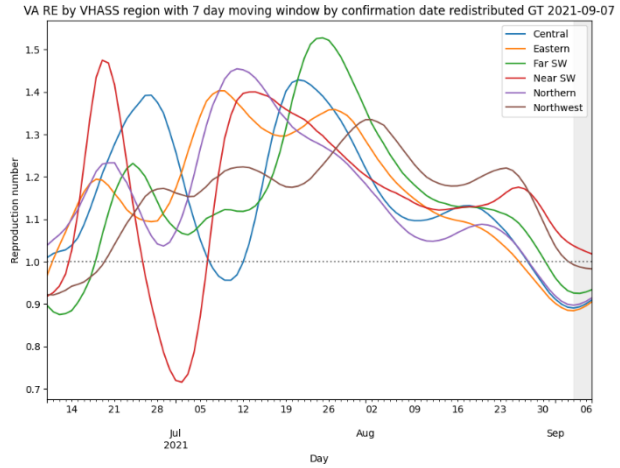
Additional Analyses

Estimating Daily Reproductive Number –
Redistributed weekend gap

Sept 6th Estimates

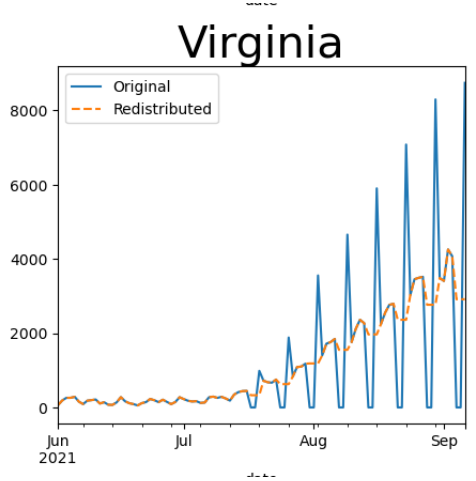
Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	0.933	-0.030
Central	0.908	-0.016
Eastern	0.905	-0.009
Far SW	0.936	-0.048
Near SW	1.019	-0.080
Northern	0.914	-0.020
Northwest	0.982	-0.083





Skipping Weekend Reports biases estimates

Redistributed Monday to fill in weekend, 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

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

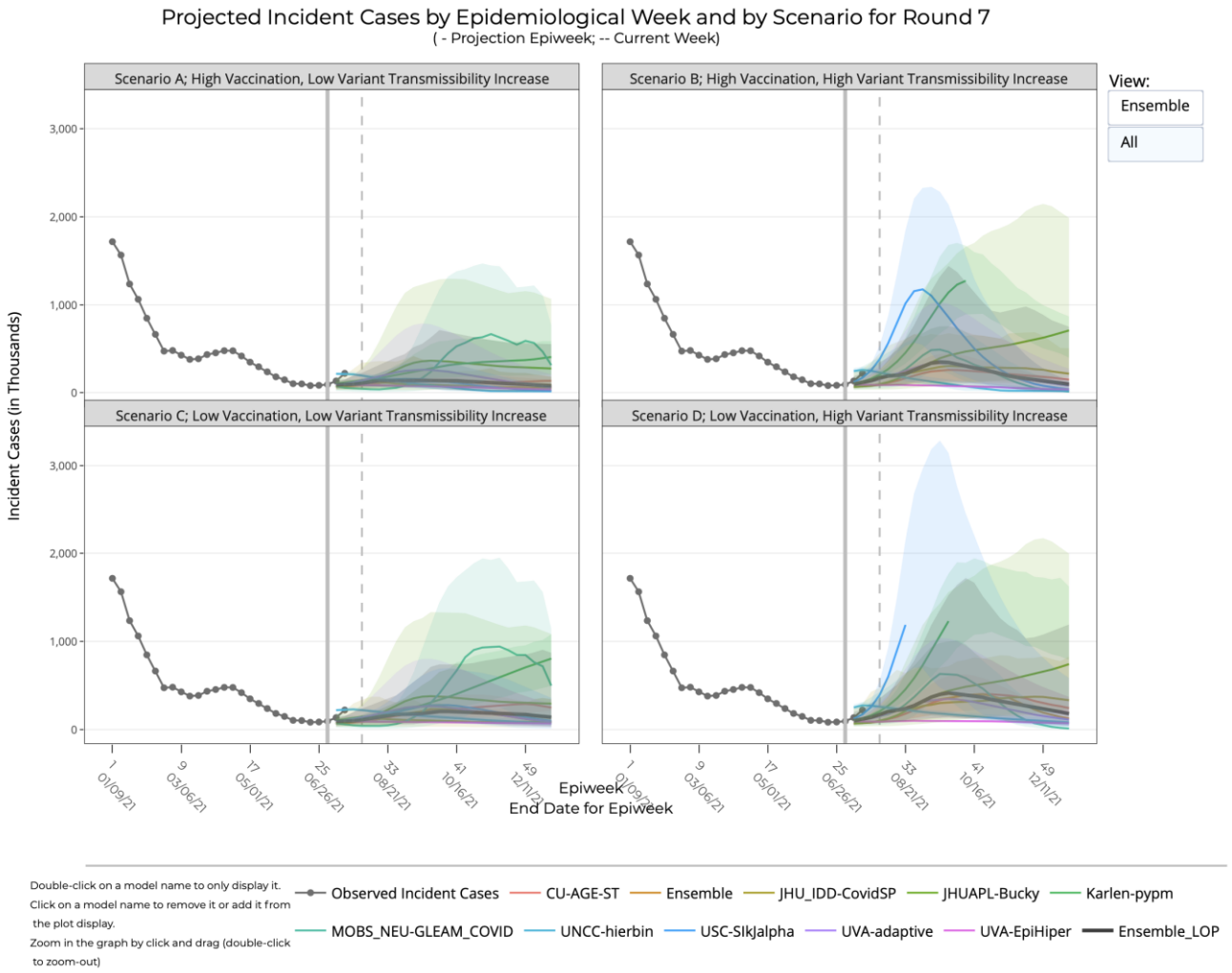
COVID-19 Scenario Modeling Hub

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

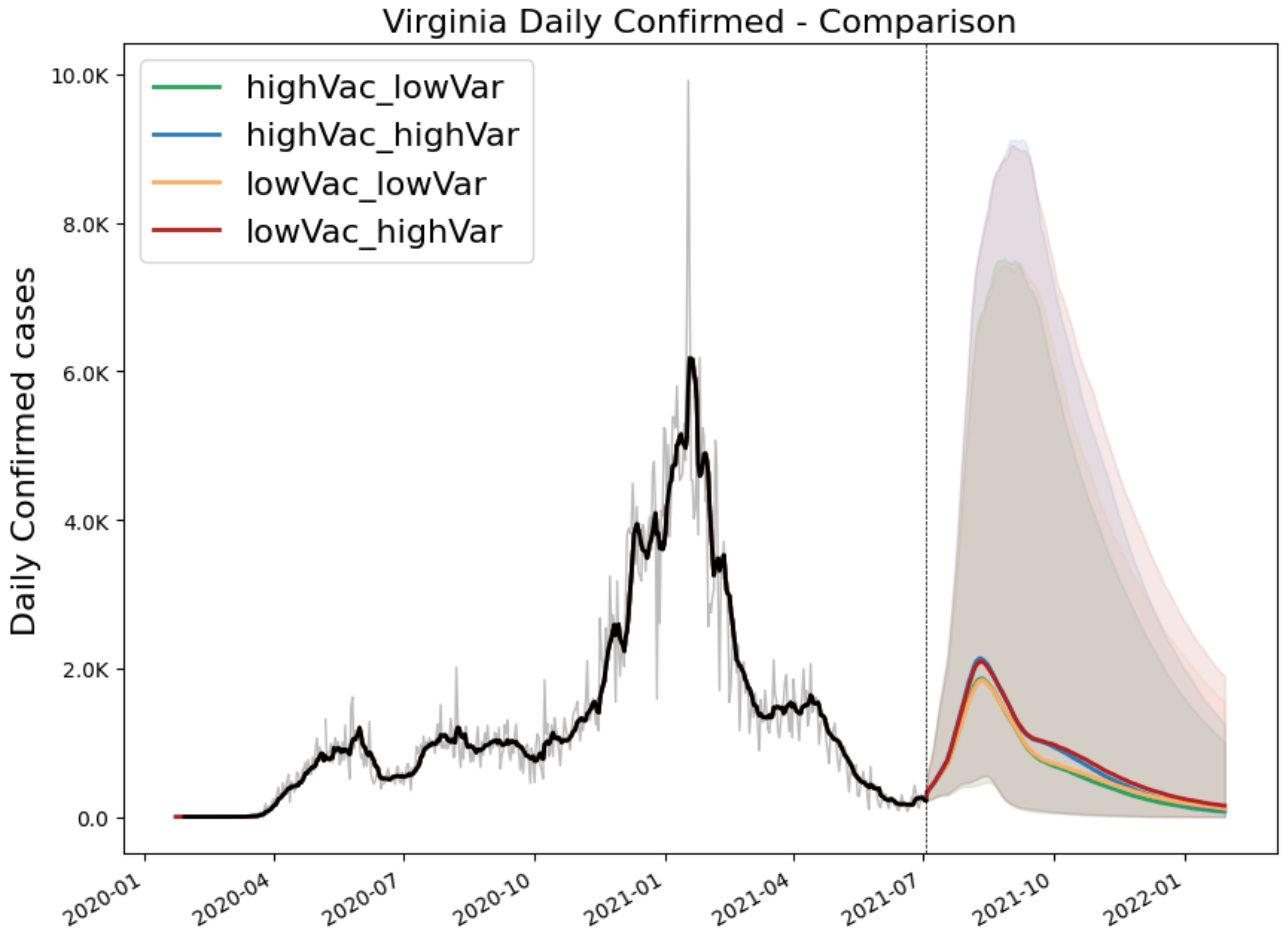
Emerging Variant Impact (5% prevalence on May 29th)

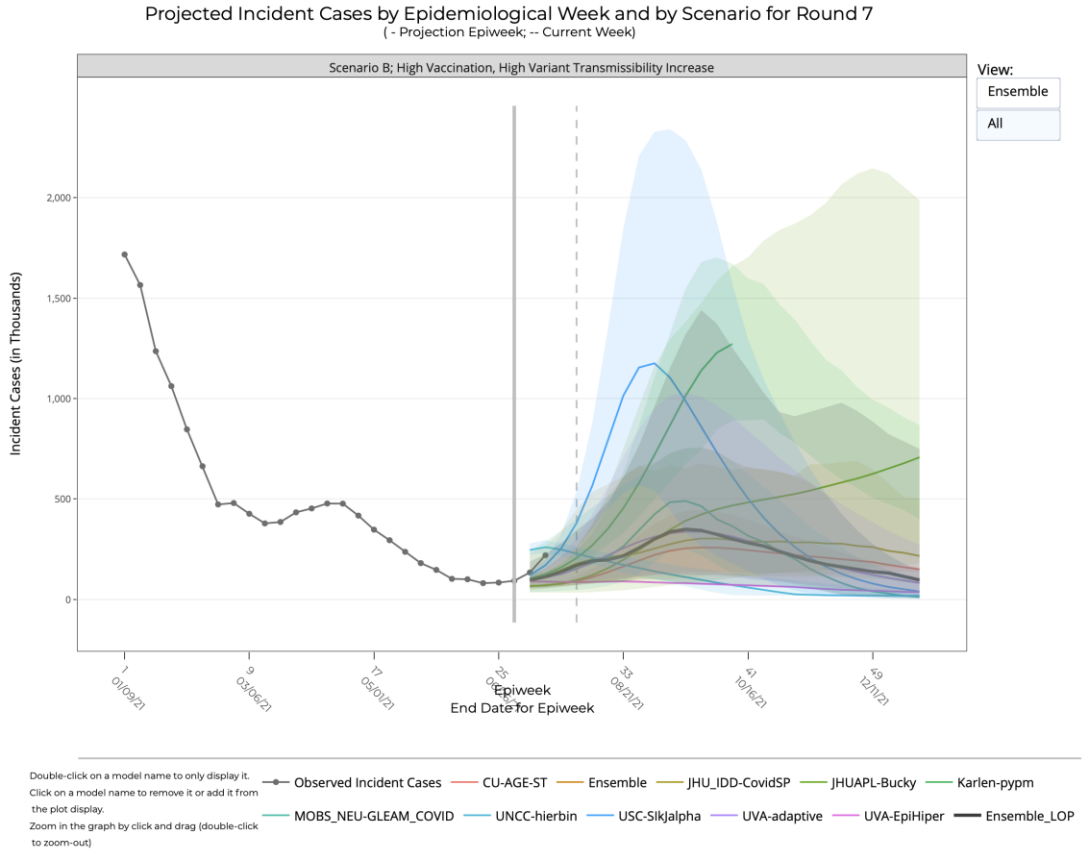
- LowVar – 40% more transmissible
- HighVar – 60% more transmissible

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

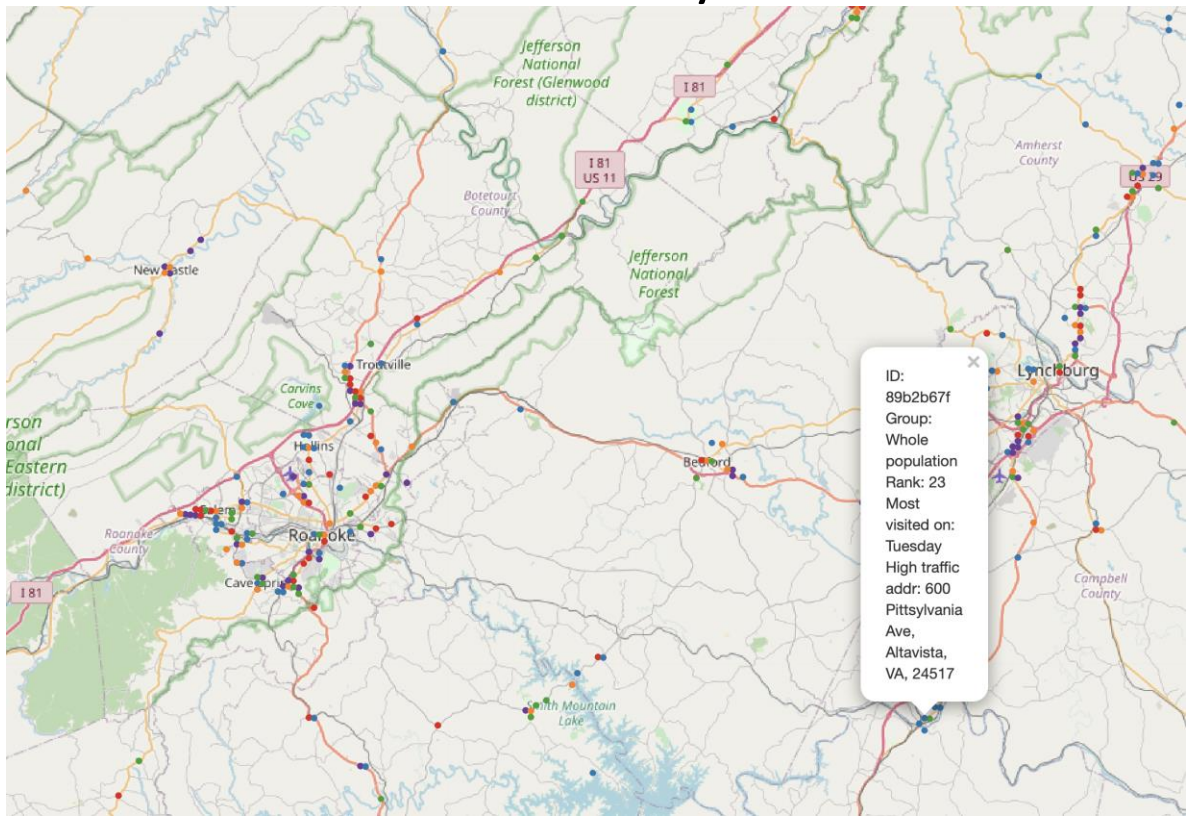
- Age stratified protection from infection
- 80% or 90% protection from hosp/death

		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	**High protection against infection and severe disease after waning**	***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	**Low protection against infection and severe disease after waning**	***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

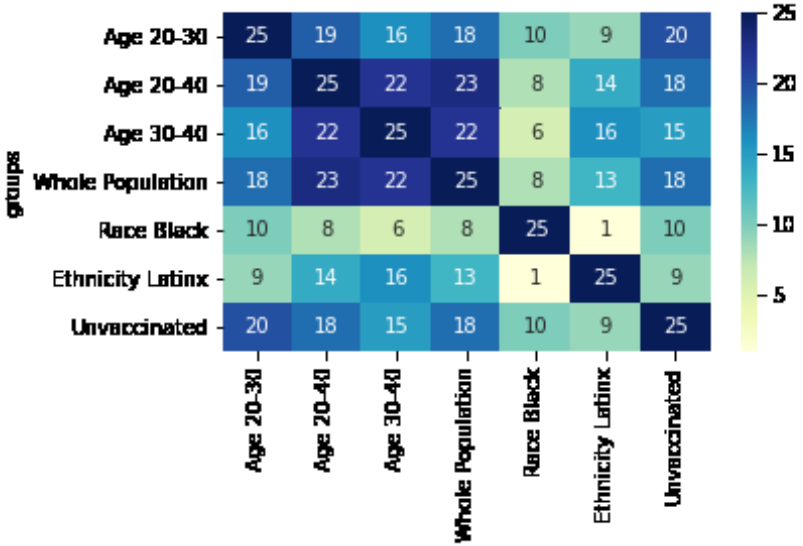
Goal: Provide frequently visited locations based on populations and vaccination levels one desires to reach

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

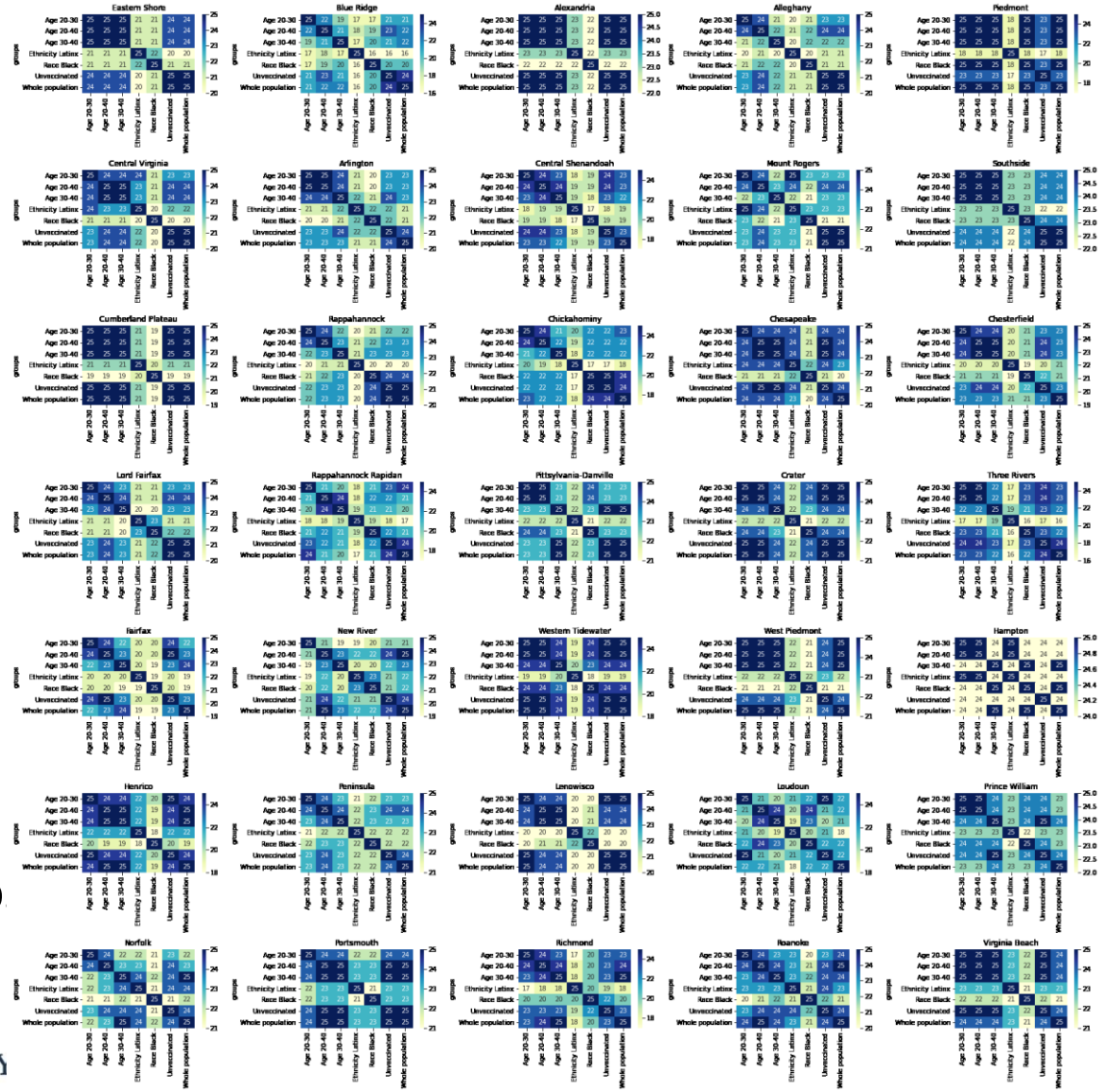
Data Recommended Mobile Vax Clinic Sites

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

References

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NSSAC. PatchSim: Code for simulating the metapopulation SEIR model. https://github.com/NSSAC/PatchSim

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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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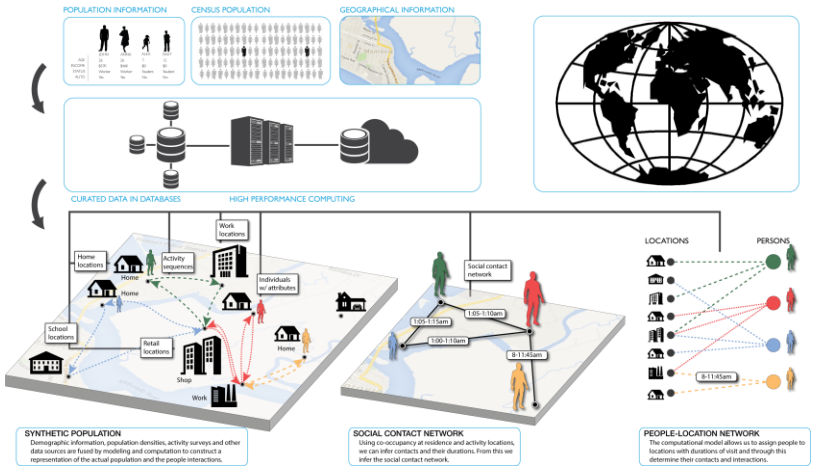
Supplemental Slides

Agent-based Model (ABM)

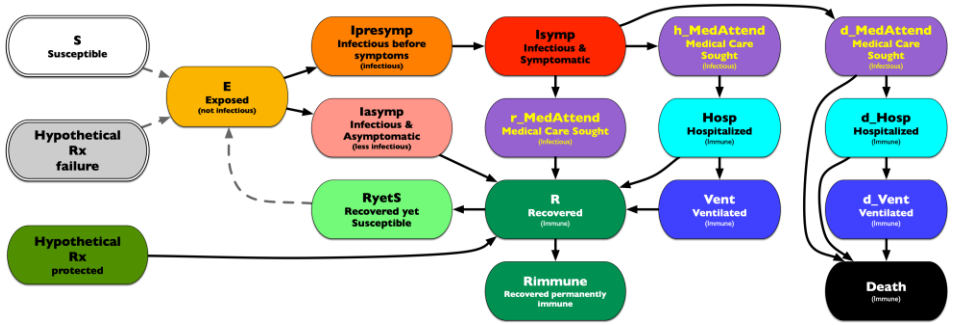
EpiHiper: Distributed network-based stochastic disease transmission simulations

- 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