Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

September 22nd, 2021

(data current to September 18th – 21st)

Biocomplexity Institute Technical report: TR 2021-106

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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

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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:

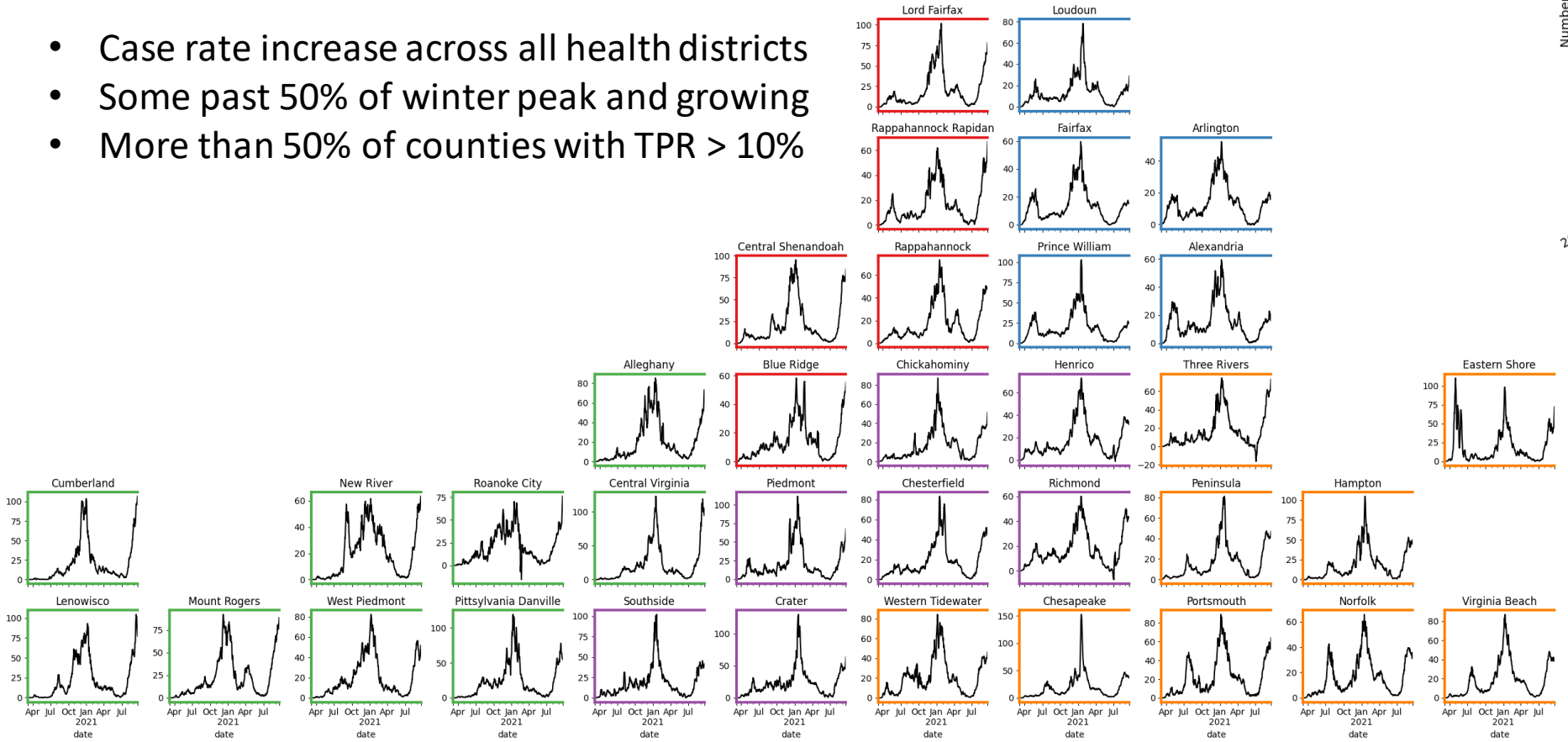
- **Case rate growth in Virginia has slowed, trends are very mixed across districts with majority also showing slow growth; case rates remain high as we may be cresting the peak of the Delta wave**
- VA 7-day mean daily incidence is slightly down to 42/100K from 43/100K; US is also slightly down to 48/100K (from 50/100K)
- Projections show a plateau and declining incidence in the near term, scenario based on last year's transmission drivers show that significant future case growth remains possible
- Recent updates:
  - Added FallWinter2020 scenario which replays the transmission drivers of last Fall-Winter season
  - Adjustment to higher levels of assumed immunity waning (natural and vaccine)

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

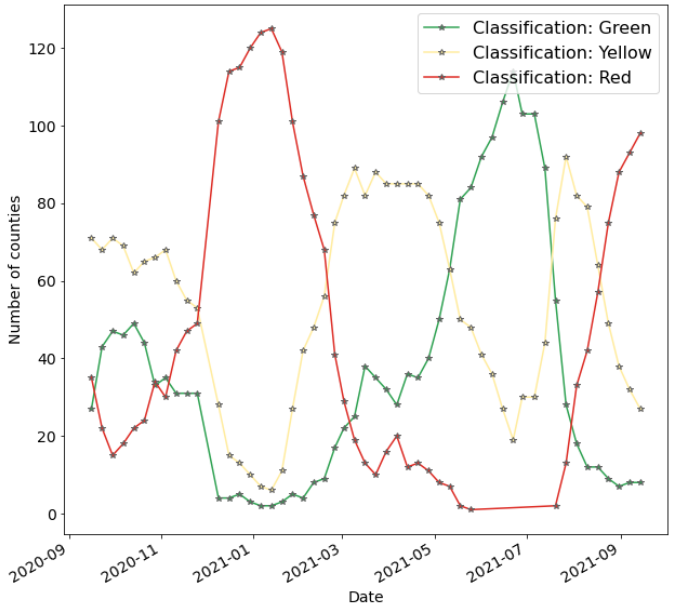
Situation Assessment

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")

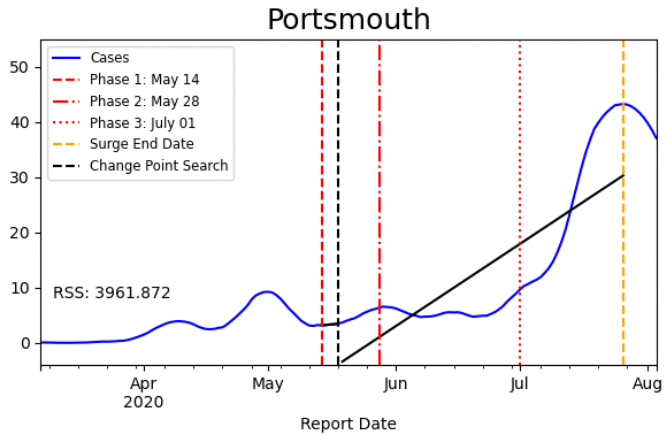
Classification date	Green	Yellow	Red
2021-06-28	103.0	30.0	0.0
2021-07-06	103.0	30.0	0.0
2021-07-13	89.0	44.0	0.0
2021-07-20	55.0	76.0	2.0
2021-07-27	28.0	92.0	13.0
2021-08-03	18.0	82.0	33.0
2021-08-10	12.0	79.0	42.0
2021-08-17	12.0	64.0	57.0
2021-08-24	9.0	49.0	75.0
2021-08-31	7.0	38.0	88.0

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

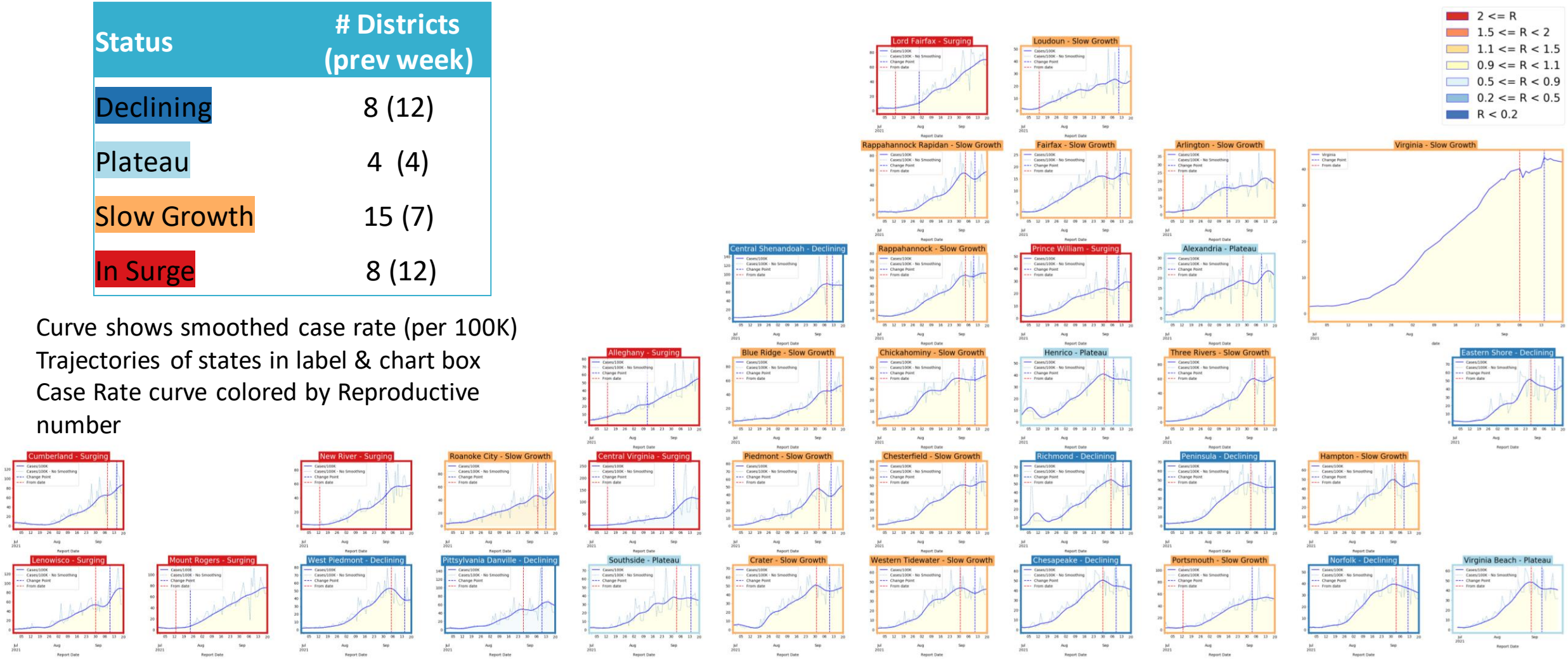


Trajectory	Description	Weekly Case Rate (per 100K) bounds	# Districts (prev week)
Declining	Sustained decreases following a recent peak	below -0.9	8 (12)
Plateau	Steady level with minimal trend up or down	above -0.9 and below 0.5	4 (4)
Slow Growth	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5	15 (7)
In Surge	Currently experiencing sustained rapid and significant growth	2.5 or greater	8 (12)

District Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	8 (12)
Plateau	4 (4)
Slow Growth	15 (7)
In Surge	8 (12)

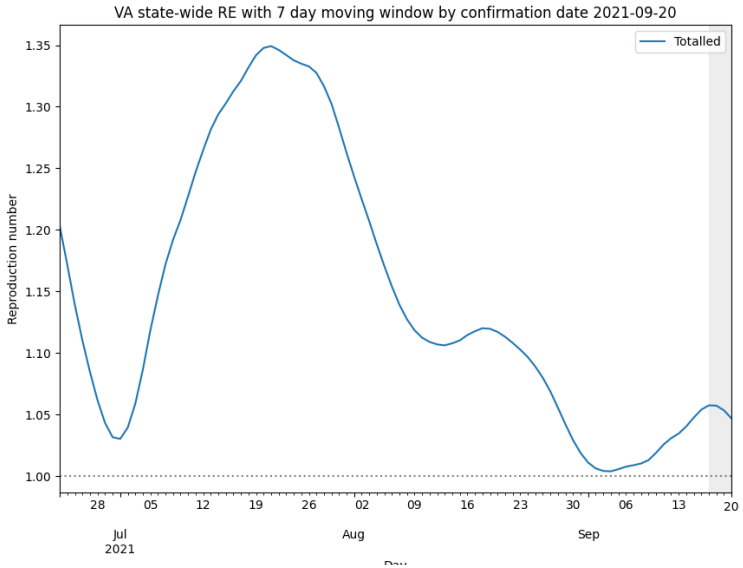
Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive number

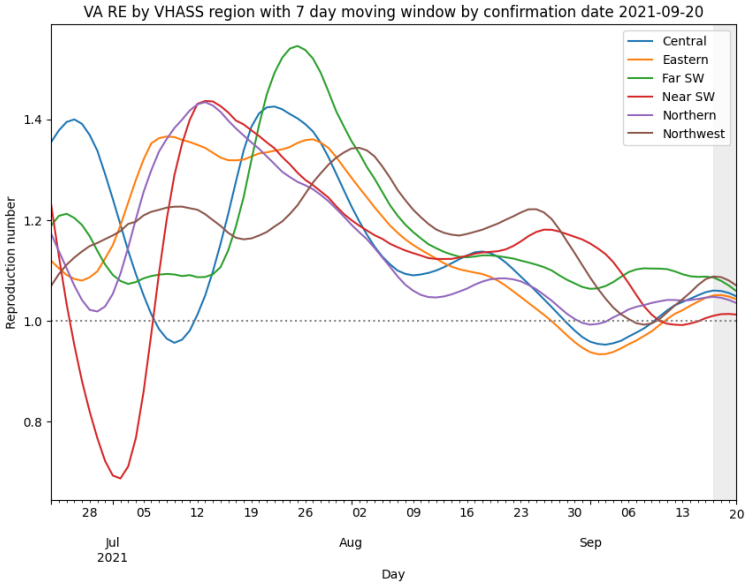


Estimating Daily Reproductive Number

Sept 20th Estimates

Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	1.047	-0.018
Central	1.049	0.012
Eastern	1.043	0.004
Far SW	1.059	-0.061
Near SW	1.013	-0.030
Northern	1.035	-0.053
Northwest	1.070	0.017





Methodology

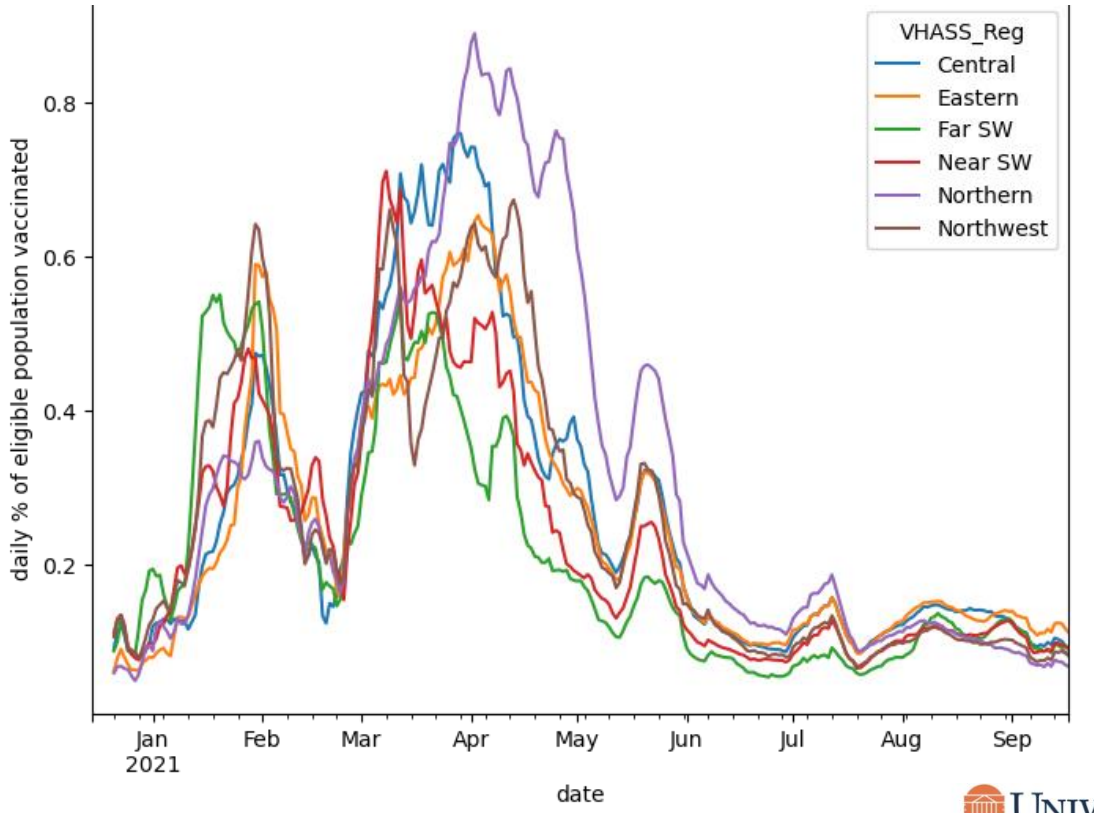
- Wallinga-Teunis method (EpiEstim[1]) for cases by **confirmation date**
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

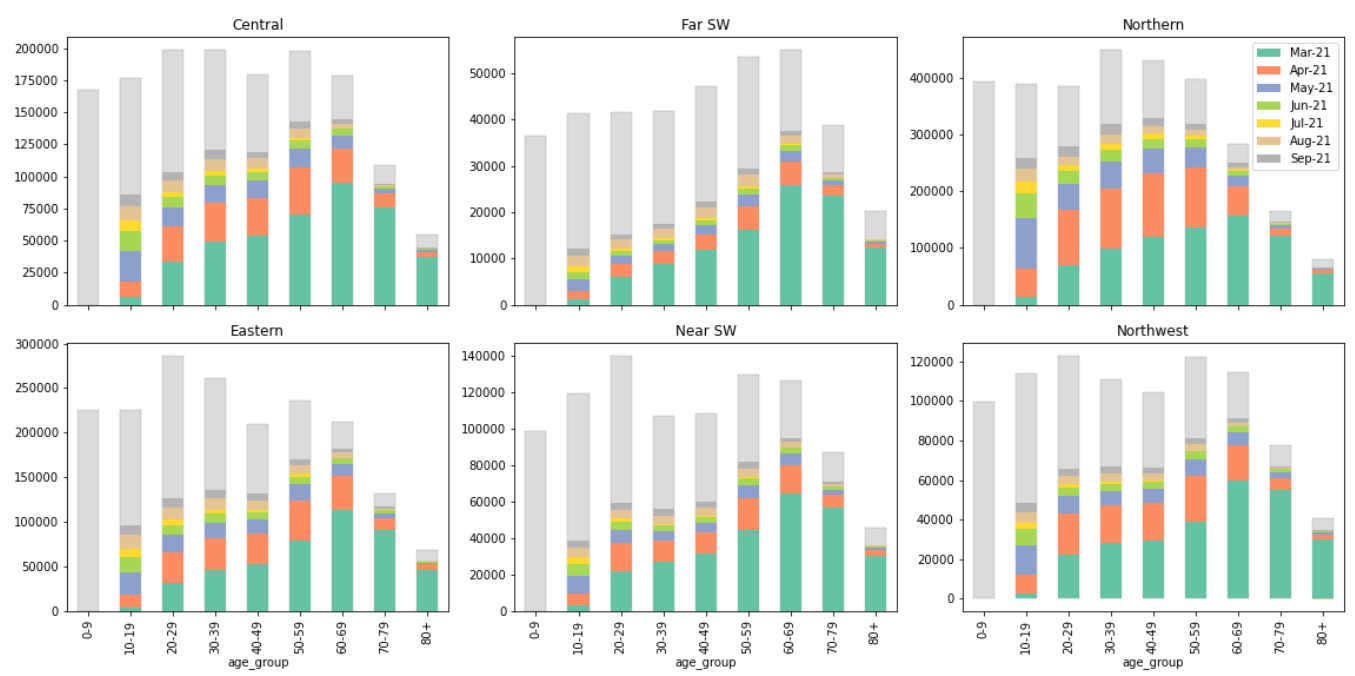
1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

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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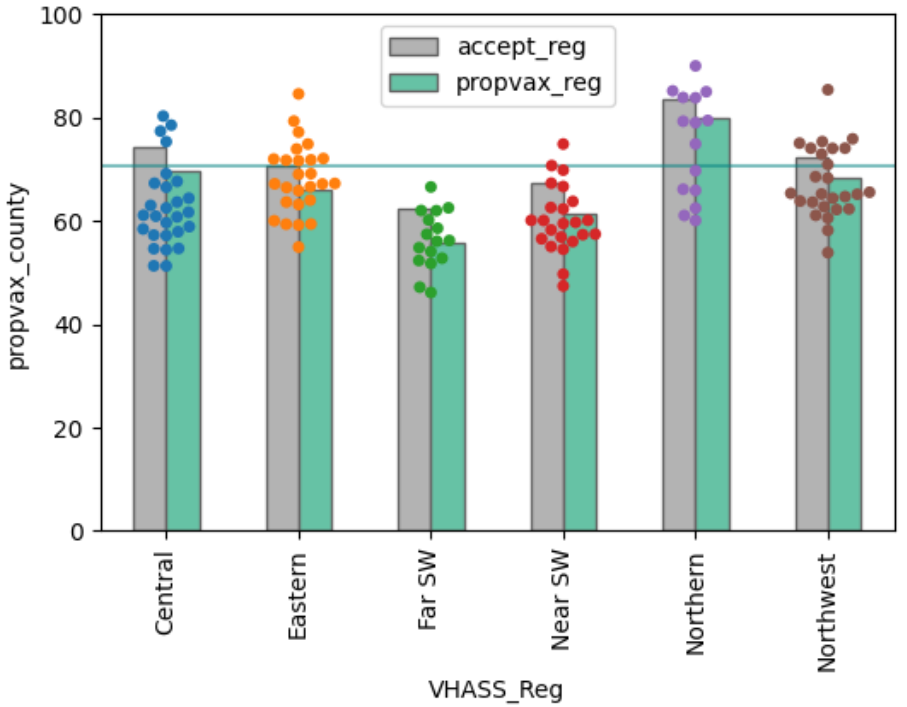
Vaccination Acceptance by Region

Corrections to surveys:

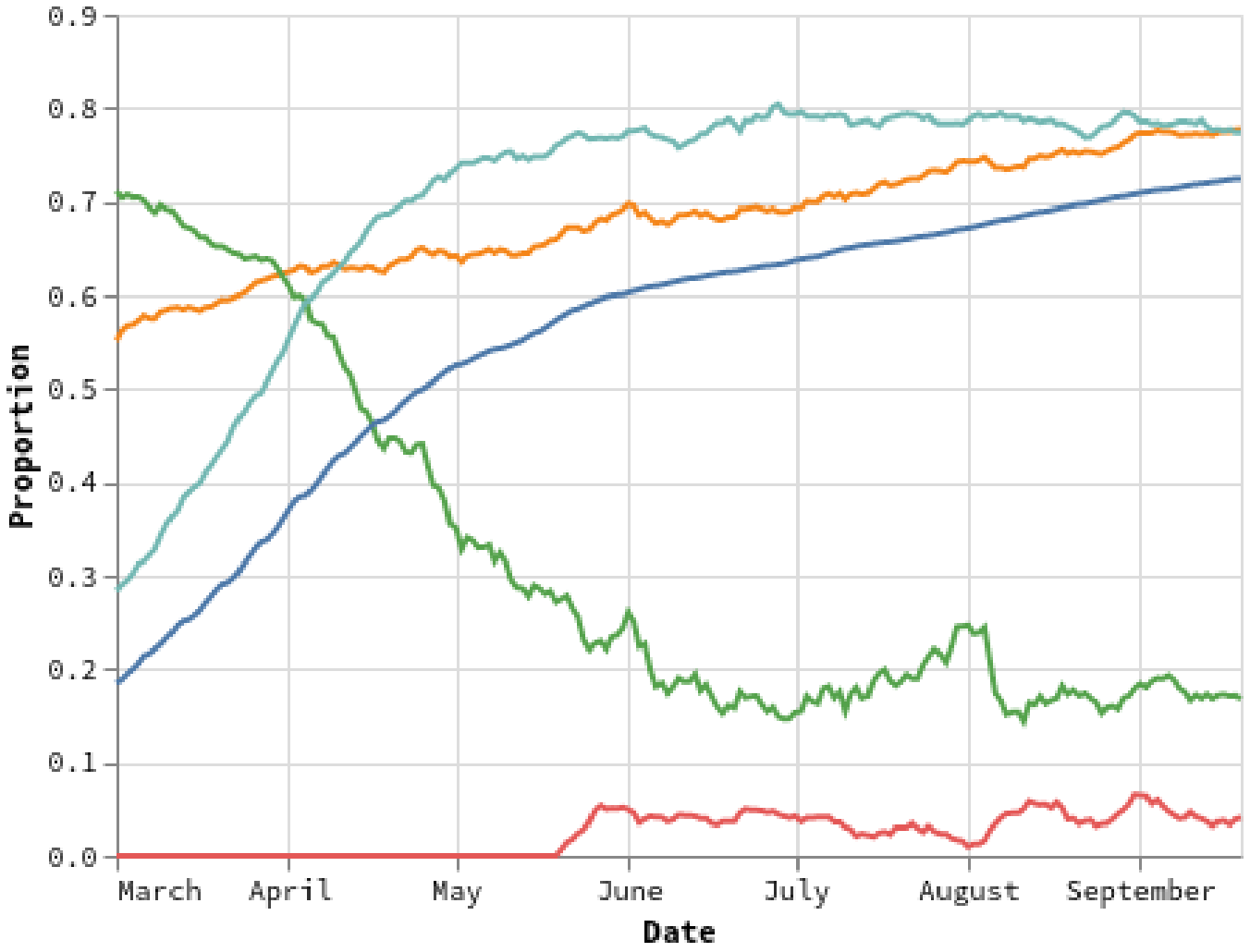
- Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
- Correction approach:
  - Calculate an over-reporting fraction based on reported vaccinations compared to VDH administration data
  - Cross-validate coarse corrections against HPS survey at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

Region	COVIDcast accepting corrected	VDH proportion pop vaccinated
Central	76%	71%
Eastern	74%	68%
Far SW	65%	57%
Near SW	70%	63%
Northern	85%	82%
Northwest	75%	70%
Virginia	**78%**	**72%**



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 appointments

- 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 have increased through August but seem to be leveling off

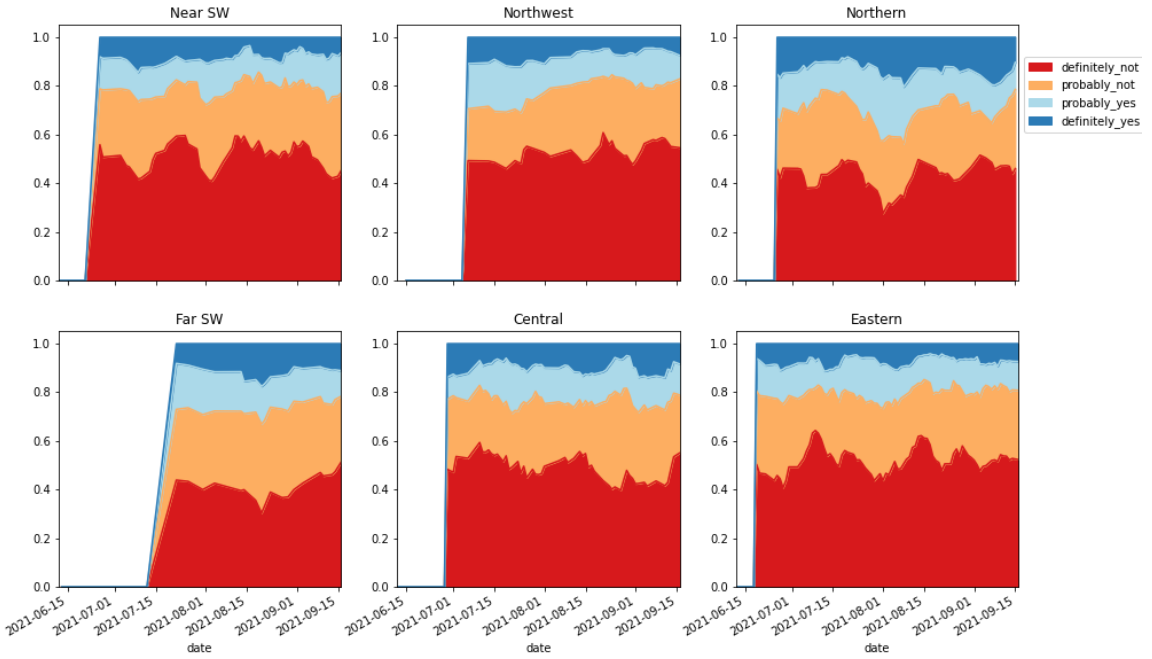
Data Source: https://covidcast.cmu.edu

Vaccine Acceptance by Region- COVIDcast

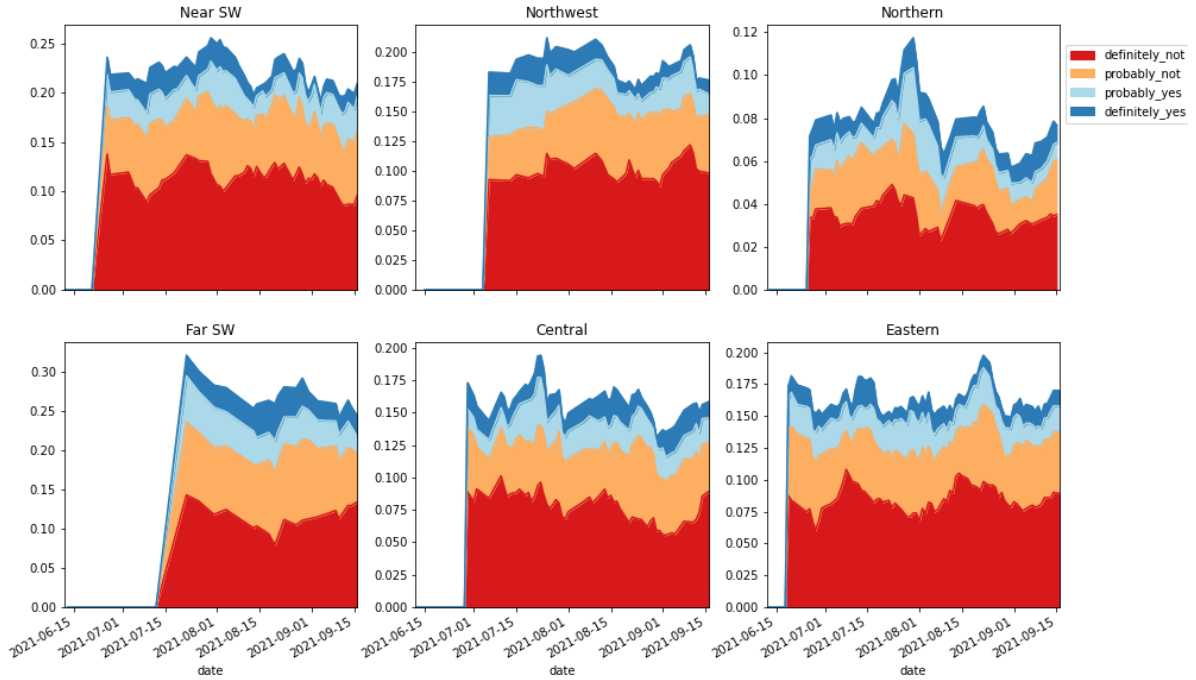
Levels of Acceptance and potential acceptance in flux:

- 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



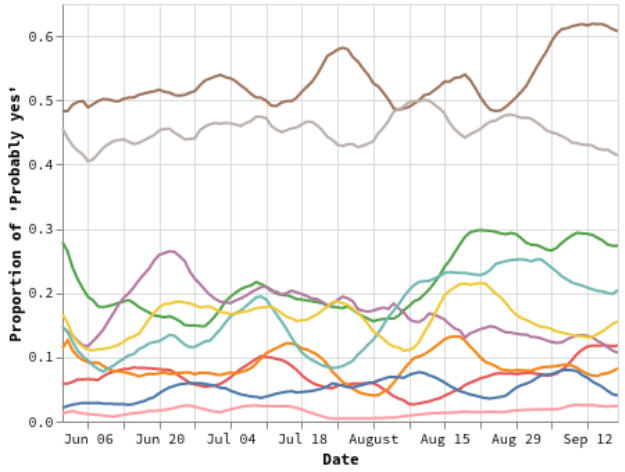
All Respondents



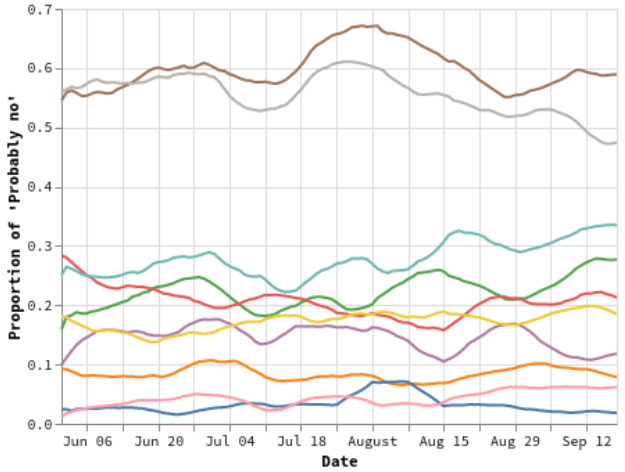
Data Source: https://covidcast.cmu.edu

Reasons for Hesitancy by Likeliness to Accept

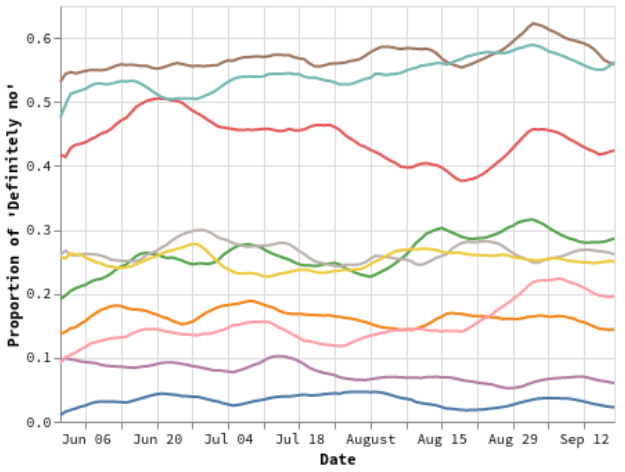
Probably Yes

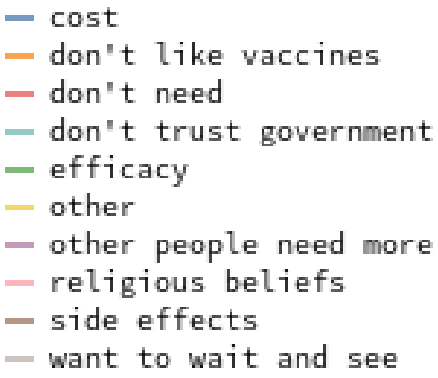


Probably No



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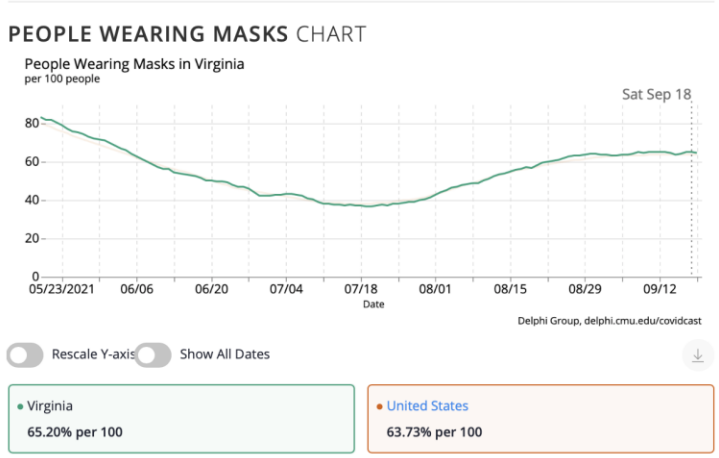
Data Source: https://covidcast.cmu.edu

Mask Usage Increases

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

- State-wide continues to rise, now outpaces US (65% vs. 64%)
- Progress in some counties has stalled or declined



VIRGINIA COUNTIES

COUNTY	CHANGE LAST 7 DAYS	PER 100	HISTORICAL TREND 8/22 – 9/19
United States	→ −0.23%	63.73% /100	9/18
Virginia	→ −0.14%	65.20% /100	9/18
Virginia Beach, VA	↓ −6.67%	57.75% /100	9/18
Newport News, VA	↓ −8.06%	59.33% /100	9/18
Chesterfield County, VA	↓ −13.97%	61.98% /100	9/18
Norfolk, VA	→ +1.10%	64.88% /100	9/18
Chesapeake, VA	→ +2.44%	65.83% /100	9/18
Henrico County, VA	↓ −5.21%	69.63% /100	9/18
Loudoun County, VA	→ −4.42%	73.22% /100	9/18
Arlington County, VA	↓ −8.27%	73.81% /100	9/18
Prince William County, VA	→ −2.14%	75.76% /100	9/18
Hampton, VA	↑ +7.70%	75.95% /100	9/18
Fairfax, VA	→ +0.60%	79.80% /100	9/18
Richmond, VA	↑ +12.14%	83.71% /100	9/18

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

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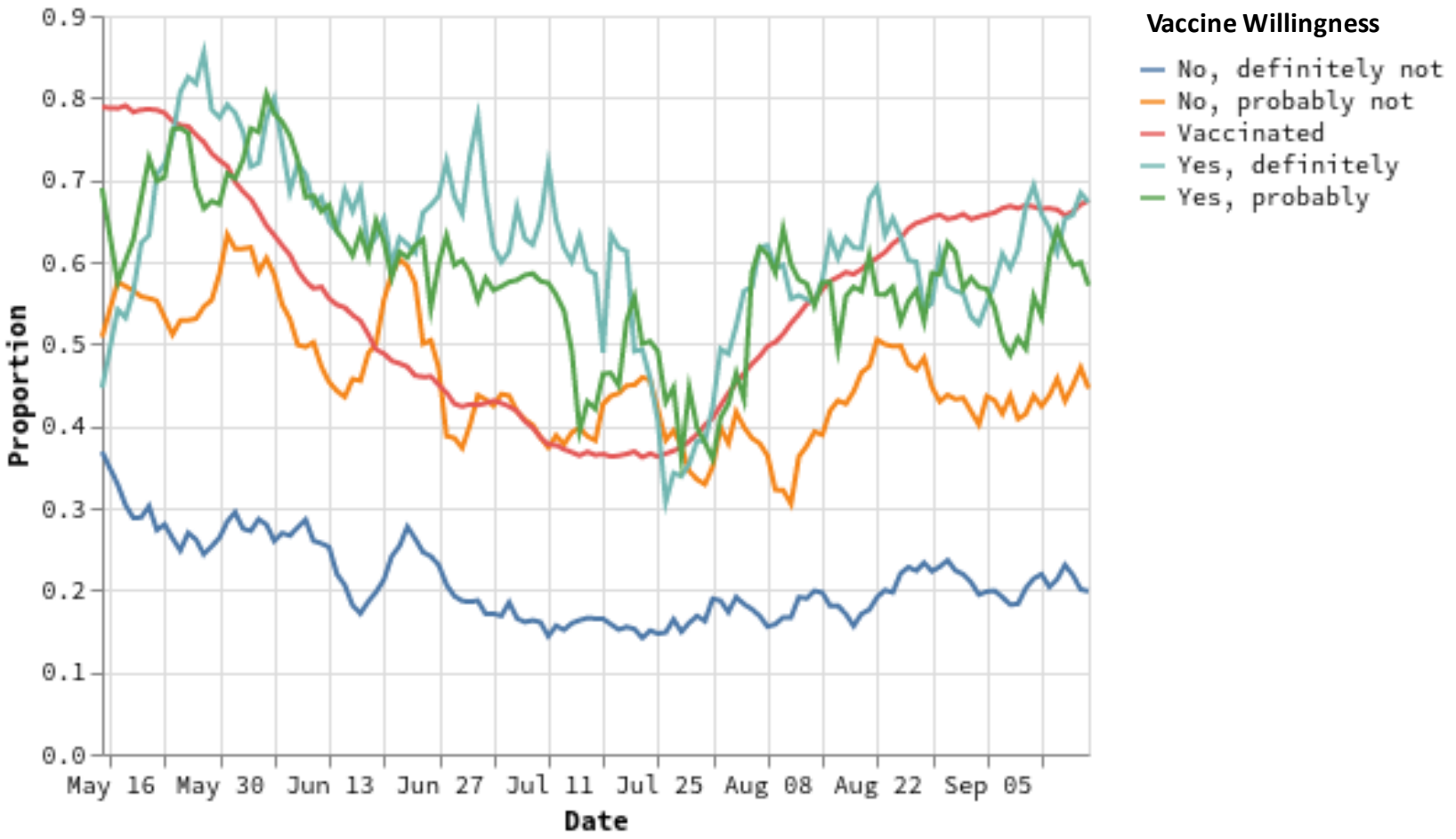
Mask Wearing by Vaccine Willingness

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 Yes joins Definitely Yes and Vaccinated with highest mask wearing over 50%



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

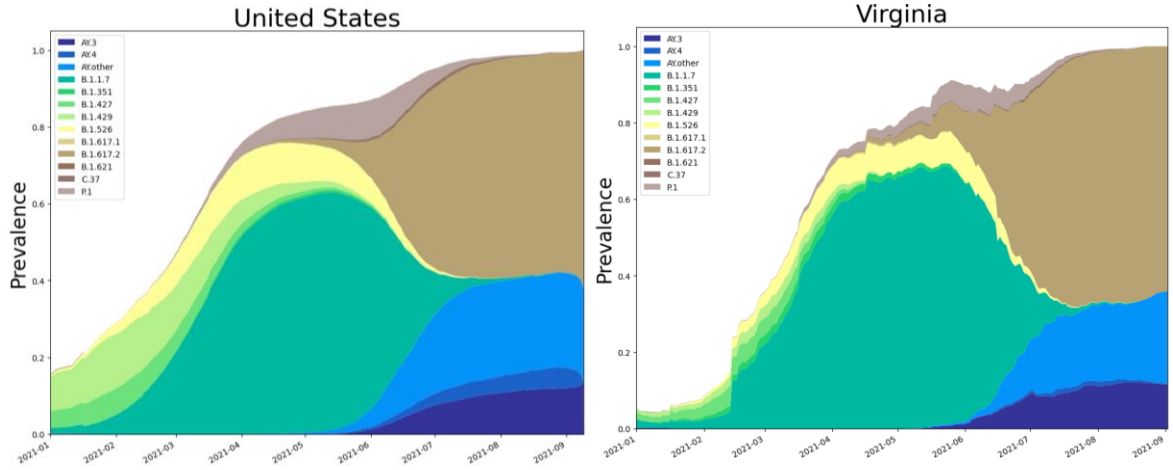
	New WHO Name	Transmissibility	Immune Evasiveness	Vaccine Effectiveness^
Ancestral		—	—	✓
D614G		+	—	✓
B.1.1.7	Alpha	+++	—	✓
B.1.351	Beta	+	++++	✓
P.1	Gamma	++	++	✓
B.1.429	Epsilon	+	+	✓
B.1.526	Iota	+	+	✓
B.1.617.2	Delta	++++*	++#	✓

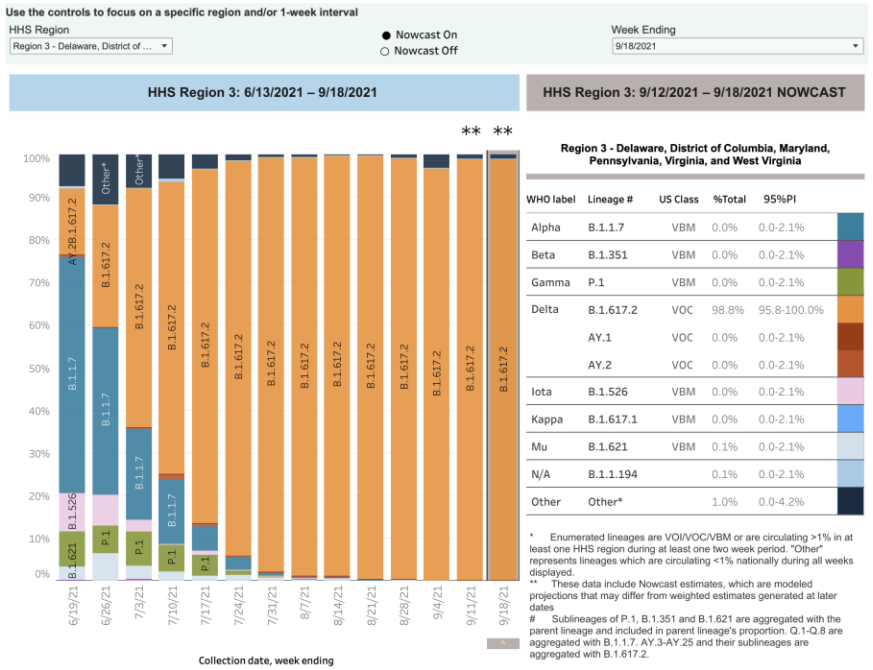
*Relative transmissibility to B.1.1.7 yet to be fully defined
^Effectiveness from real world evidence vs. severe illness, not all vaccines are effective vs all variants, and importance of 2-doses, especially for B.1.617.2 for which 1 dose of mRNA or AZ is only ~30% effective # May carry more immune escape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

World Health Organization

WHO and Eric Topol

GISAID outbreak.info



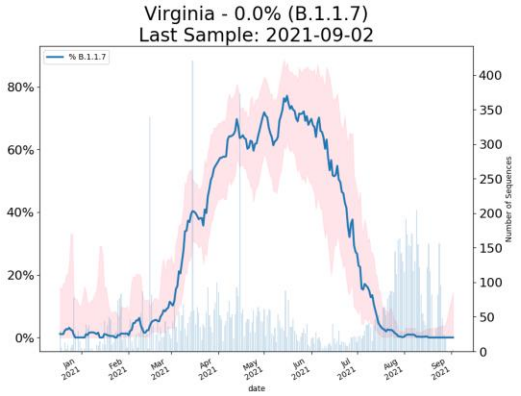


CDC Variant Tracking

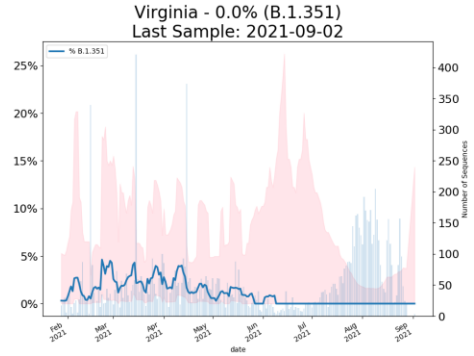
SARS-CoV2 Variants of Concern

Previous Variants

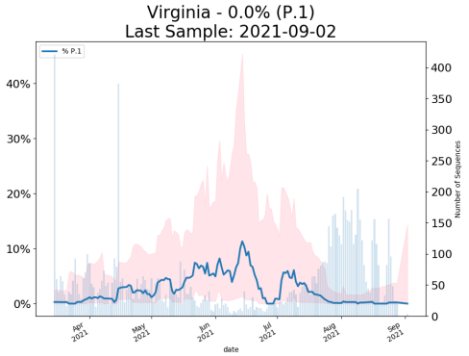
Alpha α - Lineage B.1.1.7



Beta β - Lineage B.1.351



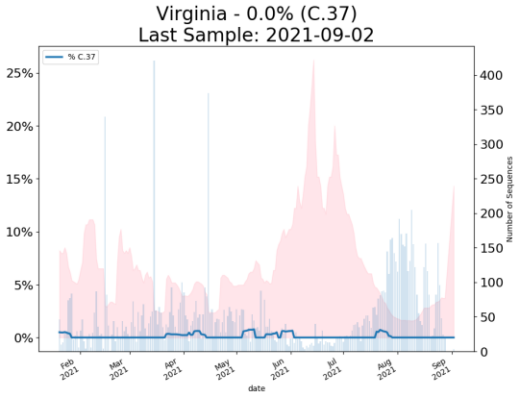
Gamma γ - Lineage P.1



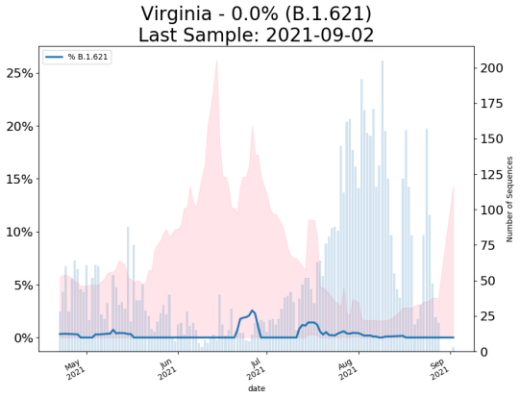
GISAID outbreak.info

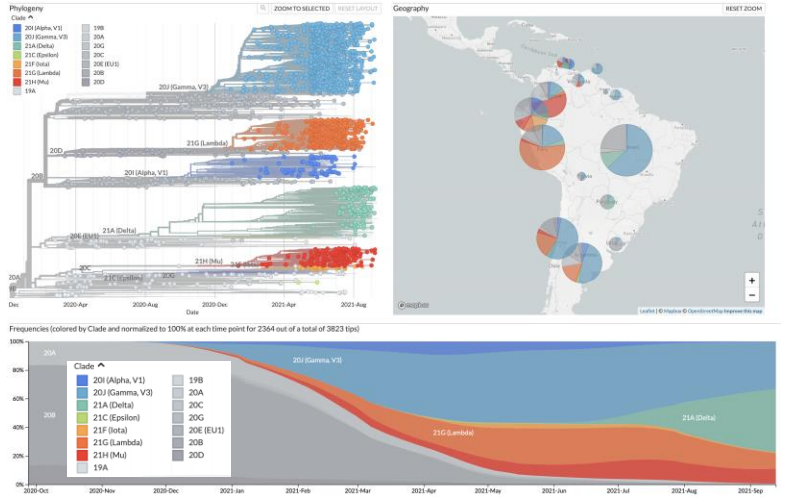
Emerging Variants

Lambda λ - Lineage C.37



Mu μ - Lineage B.1.621



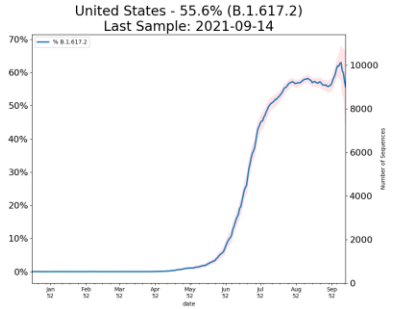


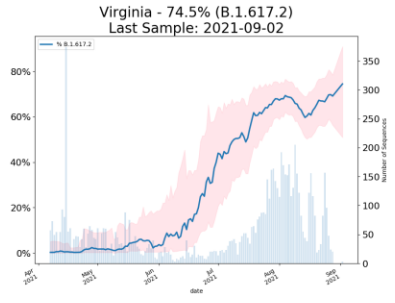
Delta continues to out compete Lambda and Mu in South America
Trevor Bedford Tweet & Nextstrain Analysis

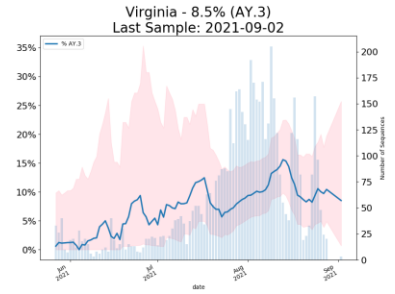
SARS-CoV2 Variants of Concern

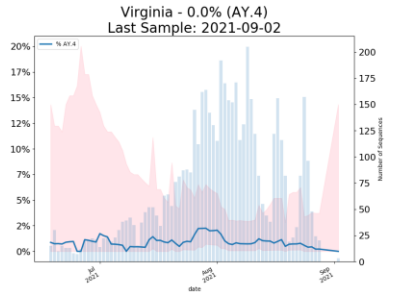
Delta δ - Lineage B.1.617.2 and related subvariants

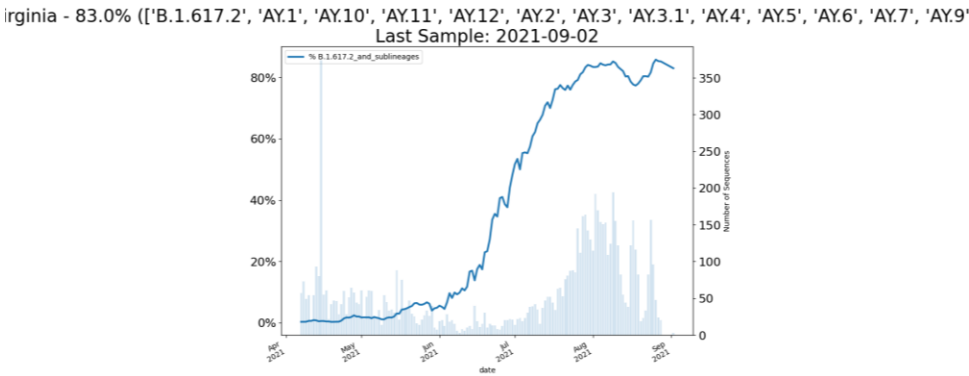
- Delta plus δ+ lineage which contains the K417N mutation is emerging as a sub-variant that is even more transmissible; declared a VoC in India
- Delta variant now dominates most of Europe and US
- CDC recommends resumption of mask wearing indoors due to reports of breakthrough infections of the vaccinated 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. Additional analysis of PHE data shows that waning in effectiveness of vaccine is strongest in oldest population, especially amongst the clinically extremely vulnerable with underlying health conditions.
2. Delta produces more infectious particles per copy of detected viral RNA than Alpha, indicating its efficiency in replication and explaining a source of enhanced transmissibility. MedArxiv
3. Update on origin of SARS-CoV2, paper from 2007 documents a clade of SARS-CoV that is genetically distinct from the SARS-CoV that caused first SARS outbreak in civets not far from Wuhan.
4. R.1 Lineage recently in the news with origins in Japan and initially found in US in Kentucky nursing home seems to have subsided and is likely outcompeted by Delta variant. Outbreak.info
5. Large claims data analysis (20M beneficiaries, with 5.5M fully vaxed) shows:
    a. In this highly vaccinated cohort (80%), there were many hospitalized breakthrough infections
    b. Strong effect of age for hospitalizations, more likely the older the person
    c. Strongest protection against hospitalization is being vaccinated after a COVID infection

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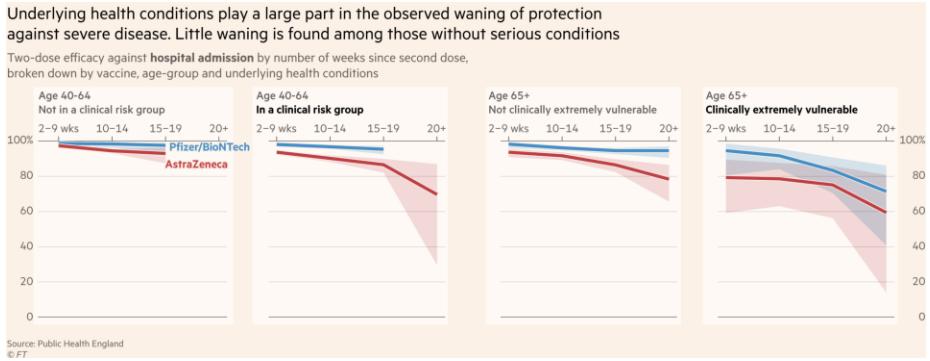

Waning of vaccine effectiveness was greater for 65+ year-olds compared to 40 to 64 year-olds. Vaccine effectiveness fell less against hospitalisations to 77.0 (70.3 to 82.3) and 92.7 (90.3 to 94.6) beyond 20 weeks post-vaccination and 78.7 (95% CI 52.7 to 90.4) and 90.4 (95% CI 85.1 to 93.8) against death for Vaxzevria and Comirnaty, respectively. Greater waning was observed among 65+ year-olds in a clinically extremely vulnerable group and 40 to 64-year olds with underlying medical conditions compared to healthy adults.. Preprint based on PHE data

vaccine effectiveness against hospitalisation - all ages (a) AstraZeneca Vaxzevria, (b) Pfizer-BioNTech Comirnaty

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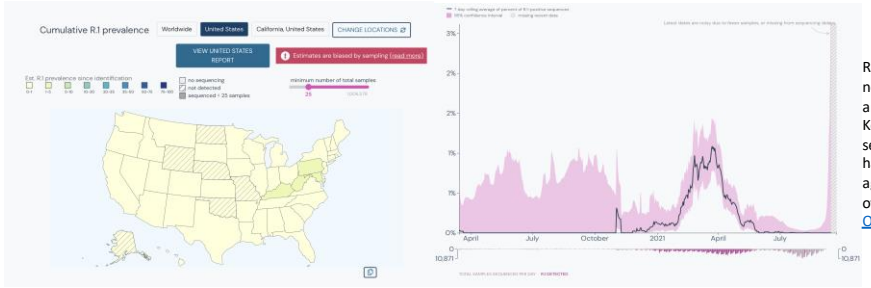
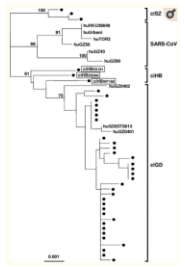


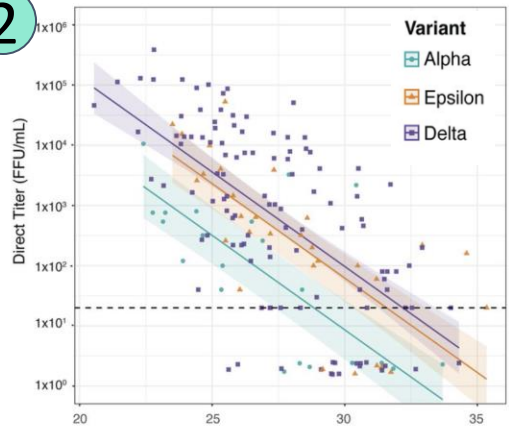
R.1 Lineage recently in the news with origins in Japan and initially found in US in Kentucky nursing home seems to have subsided and have difficulty competing against Delta variant like all other variants to date. Outbreak.info

3



This is the first report of the identification of naturally infected civets outside the Guangdong province. The discovery of civet-CoVs in the Hubei province should not be a surprise as SARS-CoV-like viruses were recently found in a bat species in the same province (16). Based on the phylogenetic analysis of S genes, the three new viruses are relatively divergent from one another and also from the viruses previously identified (Fig. (Fig.1).1) https://www.medrxiv.org/content/10.1101/2021.09.07.21263229v1.full-text

2



Both Delta and Epsilon had significantly higher infectivity than Alpha, as measured by the number of infectious units per quantity of viral E gene RNA (6 and 4 times as much, p=0.0002 and 0.009 respectively) or subgenomic E RNA (11 and 7 times as much, p<0.0001 and 0.006 respectively https://www.medrxiv.org/content/10.1101/2021.09.07.21263229v1.full-text

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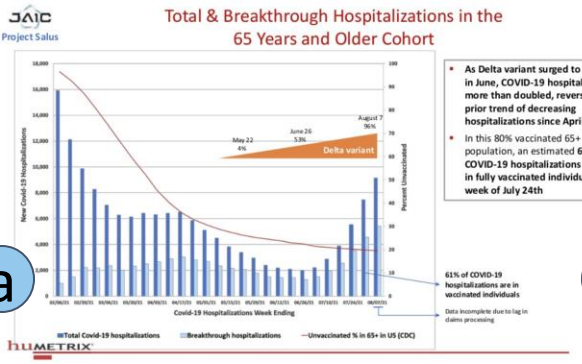

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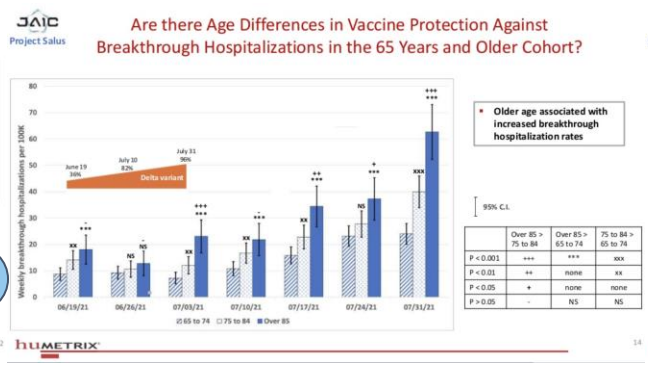

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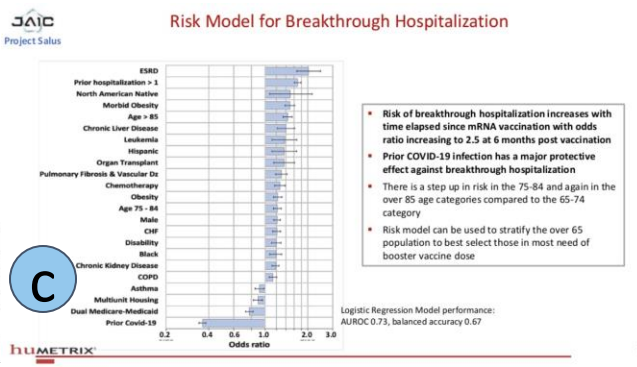


Large slideshow summary of analysis of huge cohort of Medicare beneficiaries (20M, with 16M over 65, 5.5M fully vaccinated. Several important insights on the effects of waning efficacy, level of breakthrough infections causing hospitalizations, and risk factors associated with severe breakthrough infections https://www.humetrix.com/powerpoint-vaccine.html

Variants & Vaccines – Last week

1. [Public Health England report] verifies strong protection against hospitalization and highlights that longer intervals between vaccine doses can be more efficacious, but too long may also diminish efficacy
2. Additional analyses on the PHE study above demonstrate the utility of additional doses for the most vulnerable populations, and benefits of dose gaps larger than 4 weeks.
3. [Updated analysis] on Israeli data that avoids Simpson's paradox continues to demonstrate vaccines high effectiveness against severe disease, and illustrates that lumping the under 12 population (ineligible for vaccination) into analyses can further diminish measured effectiveness
4. Study in [Science] illustrates the equivalency of low-dose Moderna mRNA vaccine with natural immunity, including longer term T-cell responses, suggesting potential for dose sharing (25µg vs. 100 µg)
5. San Francisco schools limited outbreaks and found very limited number of cases in their schools through basic low-cost infection control measures: vaccines, ventilation, HEPA filter, monitor CO2, indoor masks, and eating outside

1

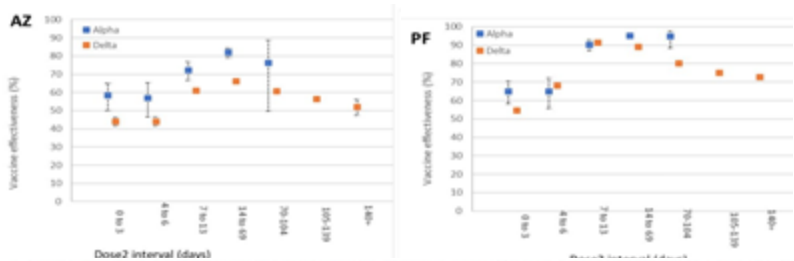
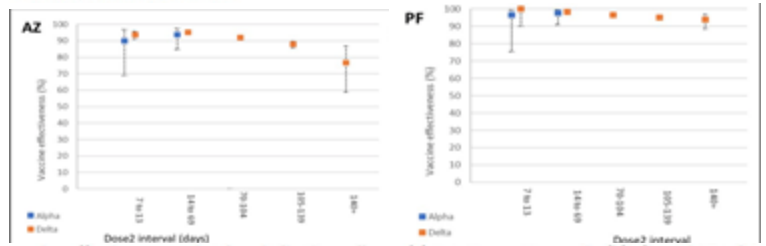


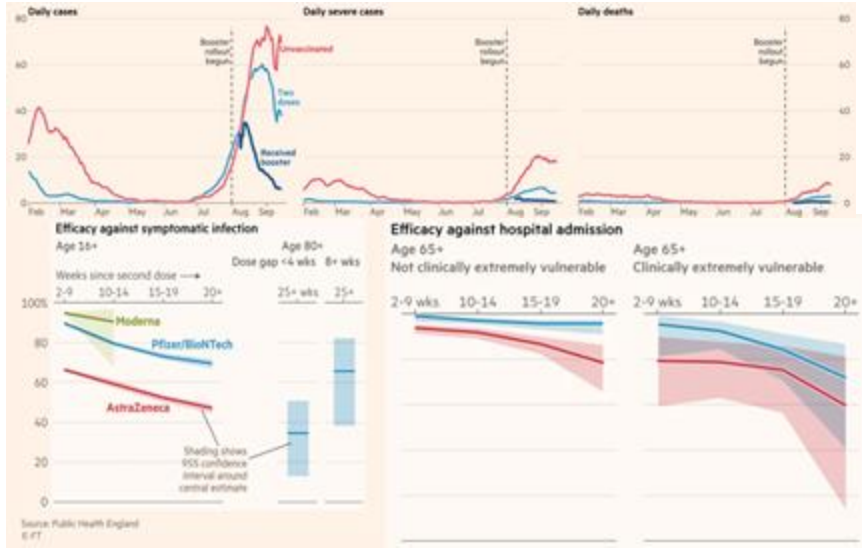
Figure 1: vaccine effectiveness against symptomatic disease - all ages (a) AstraZeneca Vaxzevria, (b) Pfizer-BioNTech Comirnaty, (c) Moderna Spikevax



vaccine effectiveness against hospitalisation - all ages (a) AstraZeneca Vaxzevria, (b) Pfizer-BioNTech Comirnaty

In a recent report PHE conducted a test negative case control design study to estimate VE against symptomatic disease, hospitalisation and death.They compared vaccination status in persons with symptomatic Covid-19 with vaccination status in persons who reported symptoms but had a negative test. This approach helps to control for biases related to health-seeking behaviour, access to testing, and case ascertainment. [PHE report]

2



A recent Financial Times article based on data from PHE raises important aspects in the case for boosters, namely 1) the dosage gap impact on immune resilience and 2) the likelihood of being infected based on waning immunity, age, and other aspects of vulnerability.
https://www.ft.com/content/cf83b3a1-fe06-4c9f-999c-7500090aee7c

3

Israel Severe Cases Aug10-Sept8 (Age<12 pulled out)
From: https://datadashboard.health.gov.il/COVID-19/general

Age	Population (%)			Total Serious Cases (per 100k)			VE_SERIOUS (% reduction relative to unvaccinated)	
	Not Vax	Vax (NB)	Boost	Not Vax	Vax (NB)	Boost	Vax (NB)	Boost
All ages	1,226,932 (17.8%)	4,446,814 (64.7%)	1,200,310 (17.5%)	9289 (757.1)	7688 (172.9)	1378 (114.8)	77.2%	84.8%
>12								
<12	2,229,128	0	0	0	0	0	*	*
12-60	1,071,666 (20.1%)	3,870,427 (72.6%)	385,137 (7.2%)	3716 (346.75)	1437 (37.1)	100 (26.0)	89.3%	92.5%
>60	157,273 (10.2%)	576,344 (37.2%)	815,106 (52.6%)	5573 (3543.5)	6251 (1084.6)	1278 (156.8)	69.4%	95.6%

- These data include all children <12yr in these data, even thought they are not eligible for vaccination. Given children are at a much lower risk of severe COVID-19, this strongly attenuates VE estimates for the <60 age group and overall, with Age<12yr as an exceptionally strong Simpson's Effect factor
- Comparing ministry tables with and without <12yr, we can estimate this group as 2,229,128.
- Assuming zero serious COVID-19 & zero vaccinations from Aug10-Sept8, the numbers change substantially.

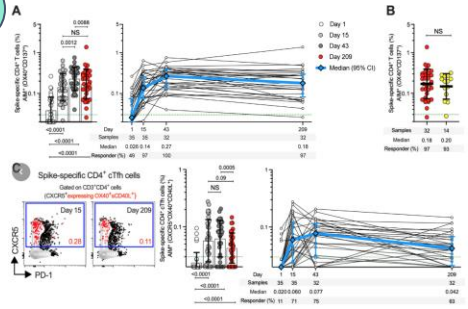
Israel Severe Cases Aug10-Sept8
From: https://datadashboard.health.gov.il/COVID-19/general

Age	Population (%)			Total Serious Cases (per 100k)			VE_SERIOUS (% reduction relative to unvaccinated)	
	Not Vax	Vax (NB)	Boost	Not Vax	Vax (NB)	Boost	Vax (NB)	Boost
All ages	3,456,060 (38.0%)	4,446,814 (48.8%)	1,200,310 (13.2%)	9289 (268.6)	7688 (172.9)	1378 (114.8)	35.6%	57.3%
<60	3,300,794 (43.7%)	3,870,427 (51.2%)	385,137 (5.1%)	3716 (112.6)	1437 (37.1)	100 (26.0)	67.0%	76.9%
>60	157,273 (10.2%)	576,344 (37.2%)	815,106 (52.6%)	5573 (3543.5)	6251 (1084.6)	1278 (156.8)	69.4%	95.6%

- The MOH data doesn't have exact counts for # vaccinated/not vaccinated/boosted for each day.
- However, they have raw counts and normalized counts per 100k for each outcome (vaccines, serious cases, deaths) from which it is possible to estimate the exact counts arithmetically. We used vaccination numbers
- These numbers change daily so here, we average over the inferred number vaccinated/not vaccinated/boosted across days.
- The numbers don't perfectly add up because of small roundoff errors in posted data, but are close enough to not substantially affect VE numbers

https://www.covid-datascience.com/post/what-do-new-israeli-data-say-about-effect-of-vaccines-boosters-vs-death-critical-severe-disease

4



Moderna vaccine stimulated cellular immunity **vaccine-generated spike-specific memory CD4+ T cells 6 months post-boost were comparable in quantity and quality to COVID-19 cases**, Spike-specific CD8+ T cells were generated in 88% of subjects, with equivalent memory at 6 months post-boost compared to COVID-19 cases.
https://www.science.org/doi/10.1126/science.abj9853

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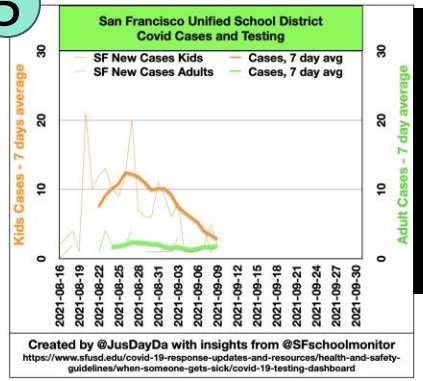
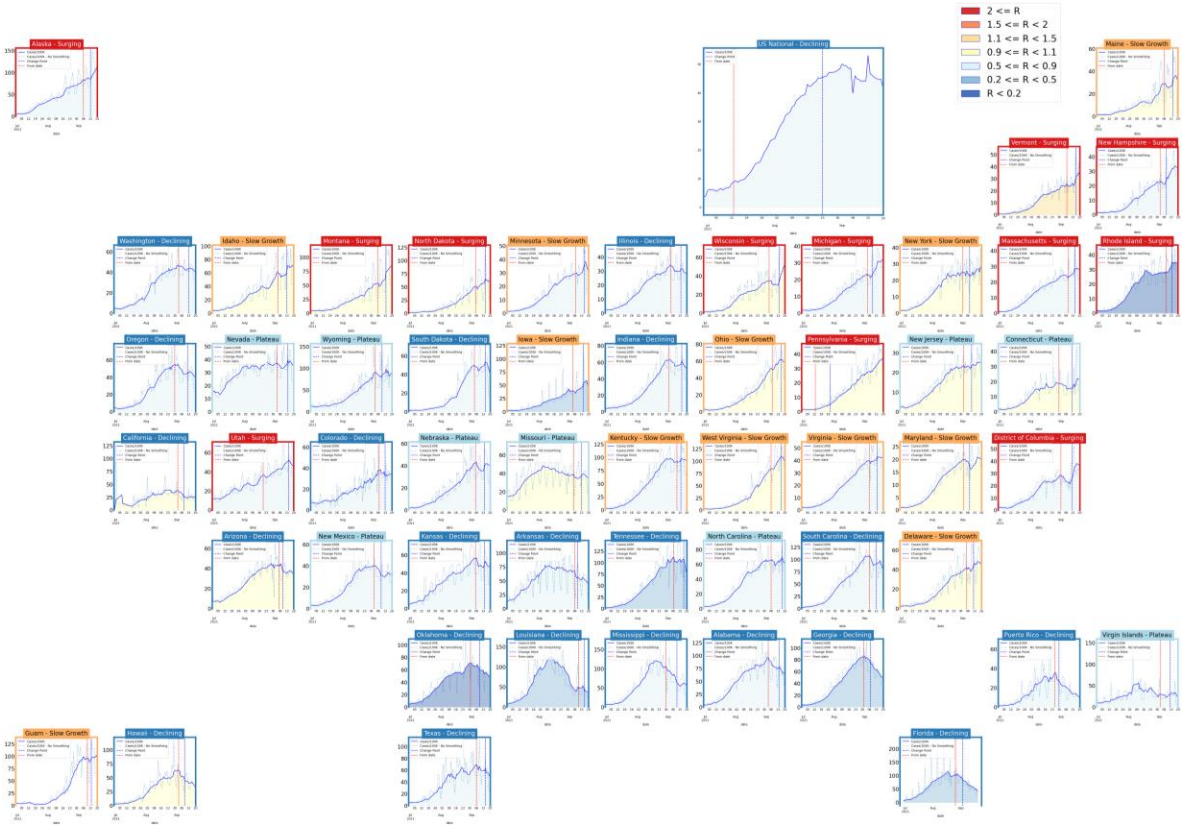


Twitter

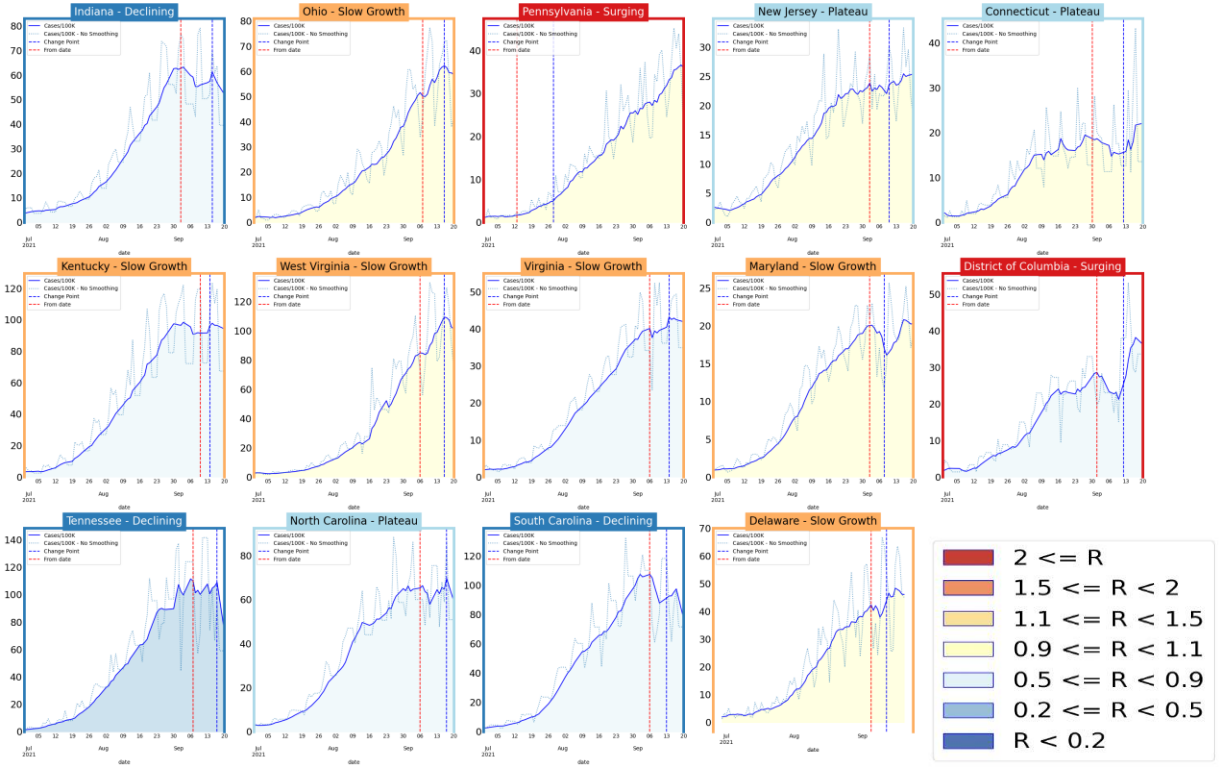
Other State Comparisons

Trajectories of States



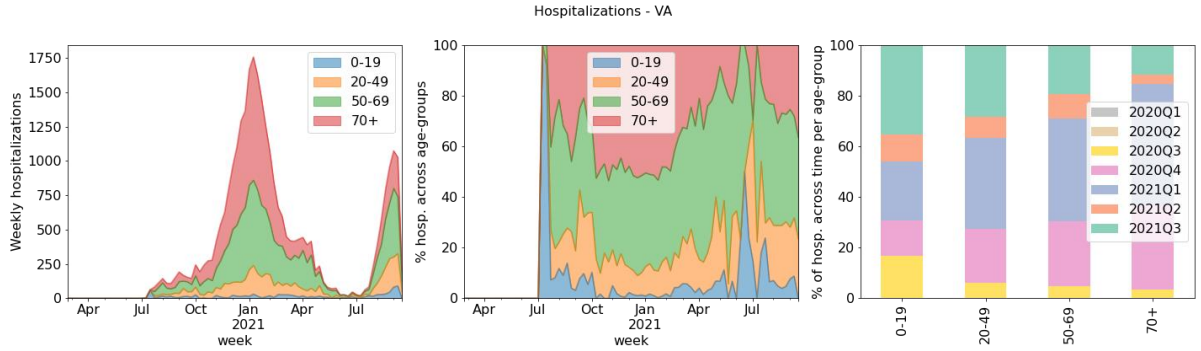
- More of the country has plateaued and started to decline
- Many states remain in surge, but show signs of slowing
- Case rates remain very high, but nationally rates are starting to come down

Virginia and her neighbors



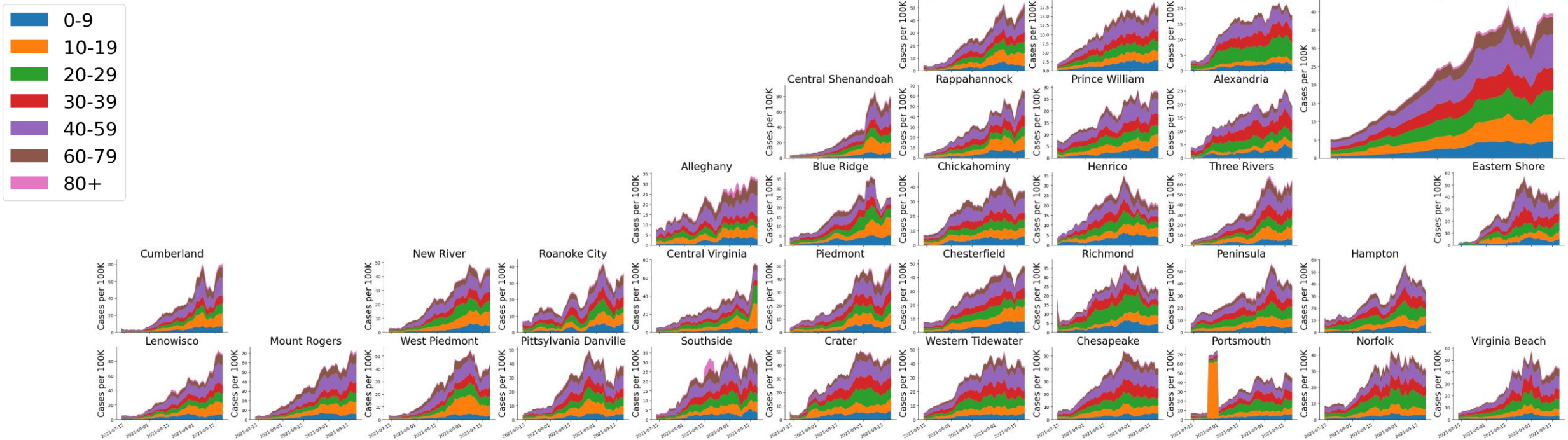
- Nearly all states show signs of plateau or slowing growth, with several declining in the past week
- Case rates remain high

Age-Specific Case Rates



Case Rates (per 100K) by Age Groups

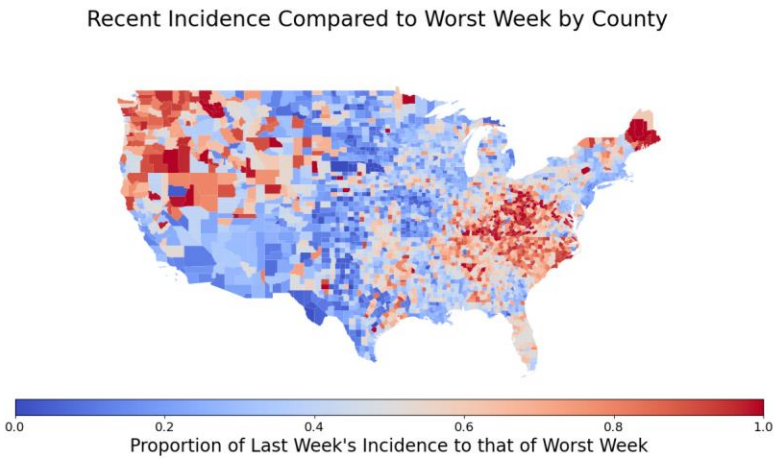
- Rapid growth in many regions in the 0-19 age range, many exceeding 20% of current case rates (nearly 10% for 0-9)
- Case rate in under 40 group far exceeds 40+ in all districts

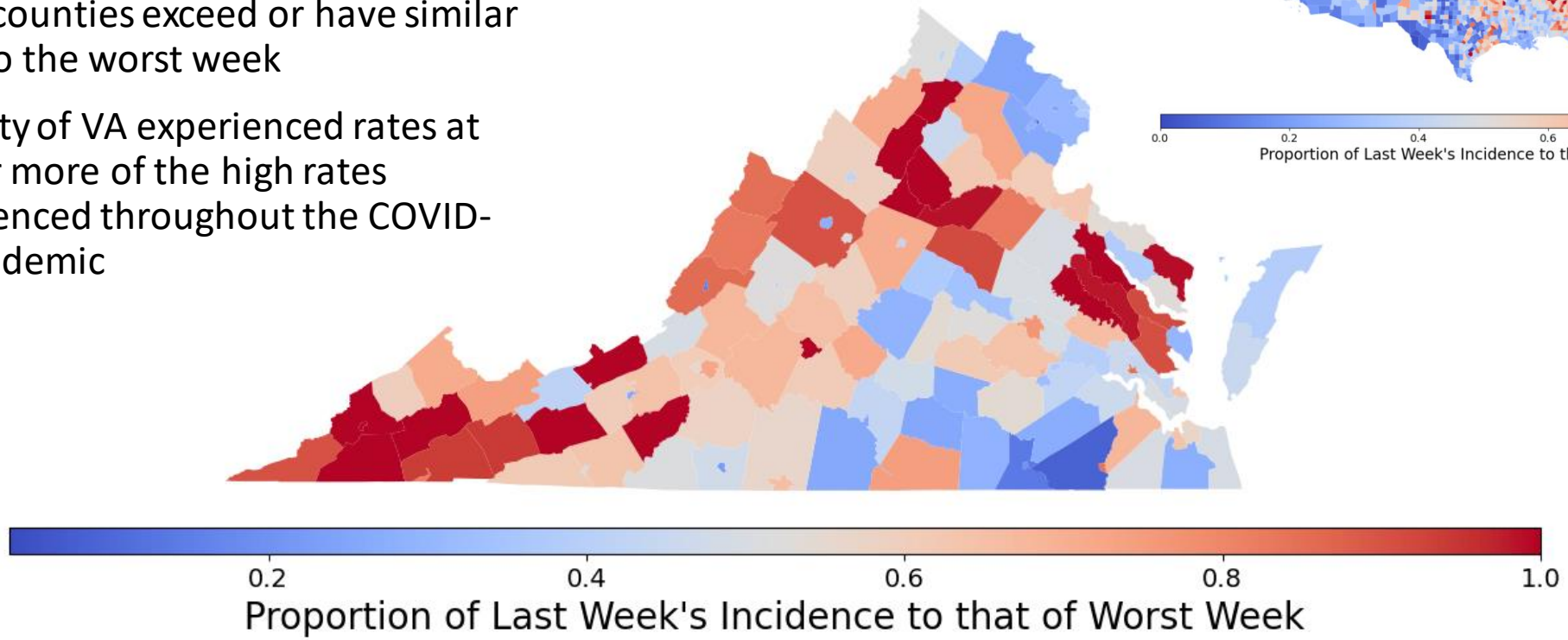


Last Week compared to worst week of Pandemic

County level Case Rates (per 100K) from last week compared to worst week of the entire pandemic

- Many counties exceed or have similar rates to the worst week
- Majority of VA experienced rates at 50% or more of the high rates experienced throughout the COVID-19 pandemic





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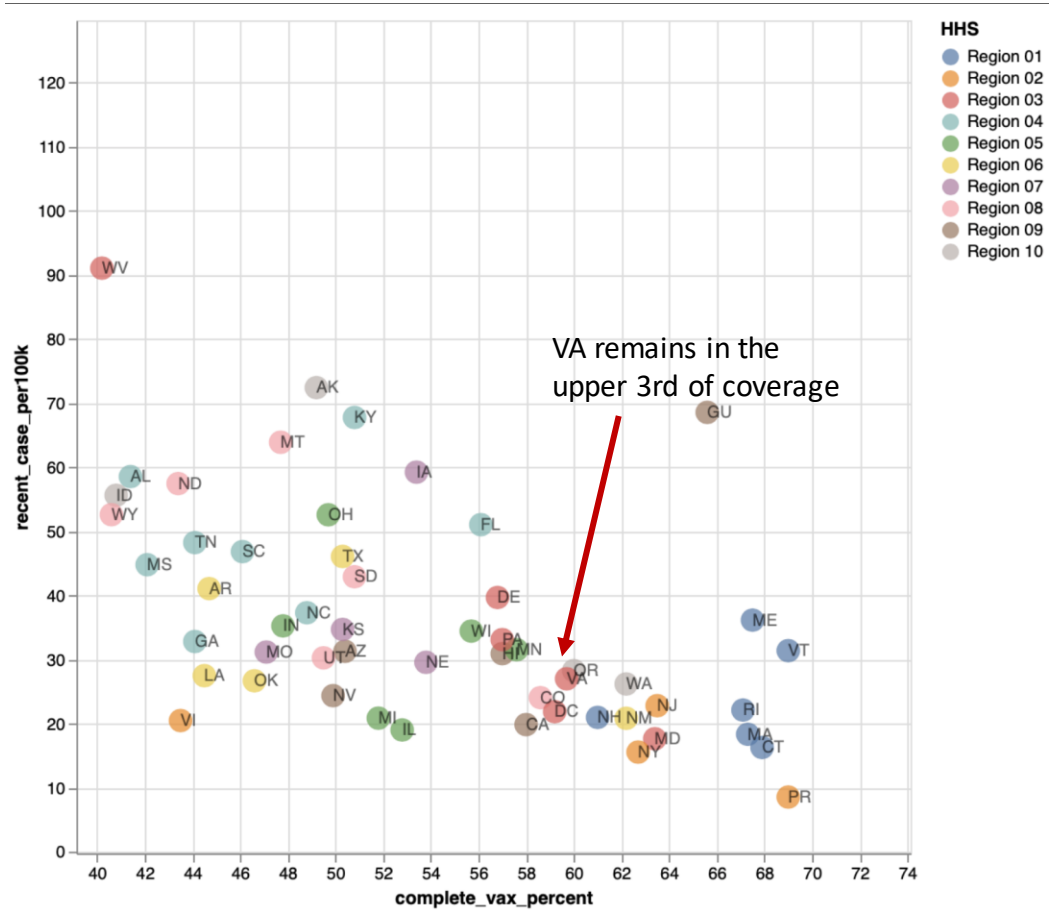
Recent Cases Correlate with Vax Coverage

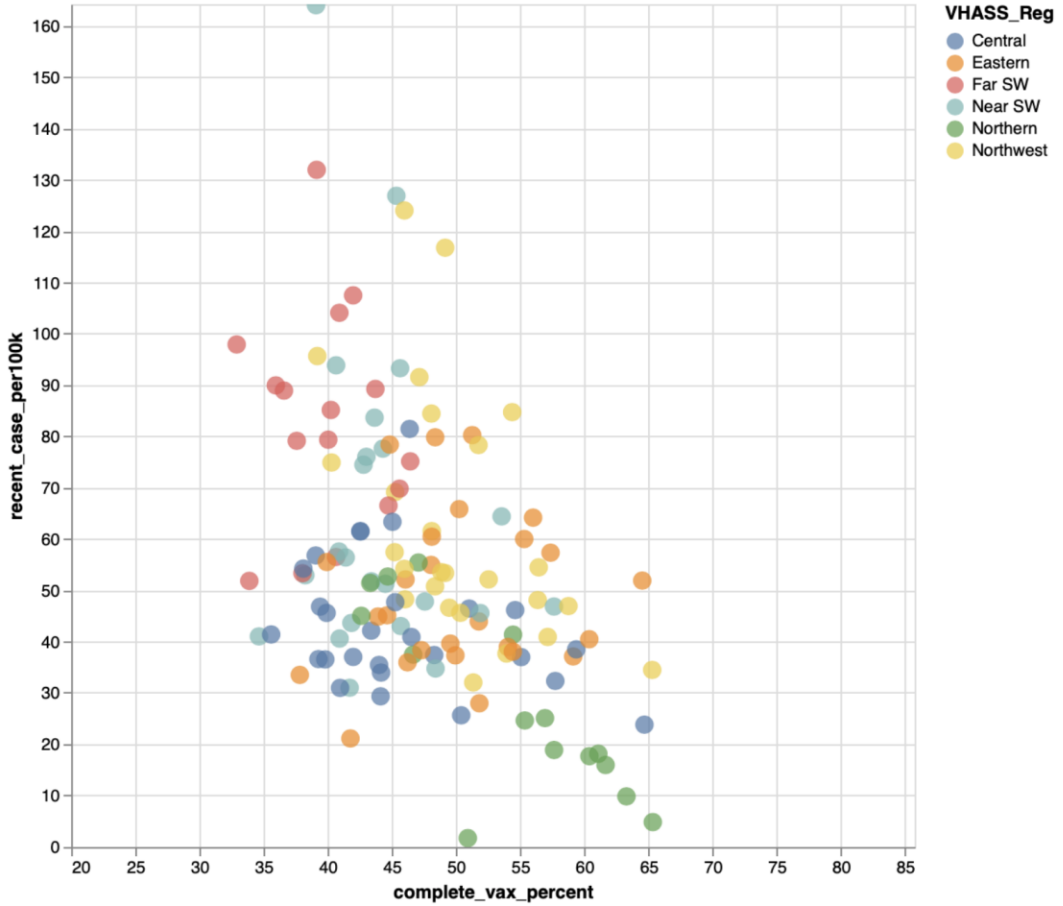
Mean cases per 100K vs. vaccine coverage

- States with lower vax coverage have had the worst case spikes



Virginia Counties

- Counties with higher vax coverage are maintaining lower case rates



Zip code level weekly Case Rate (per 100K)

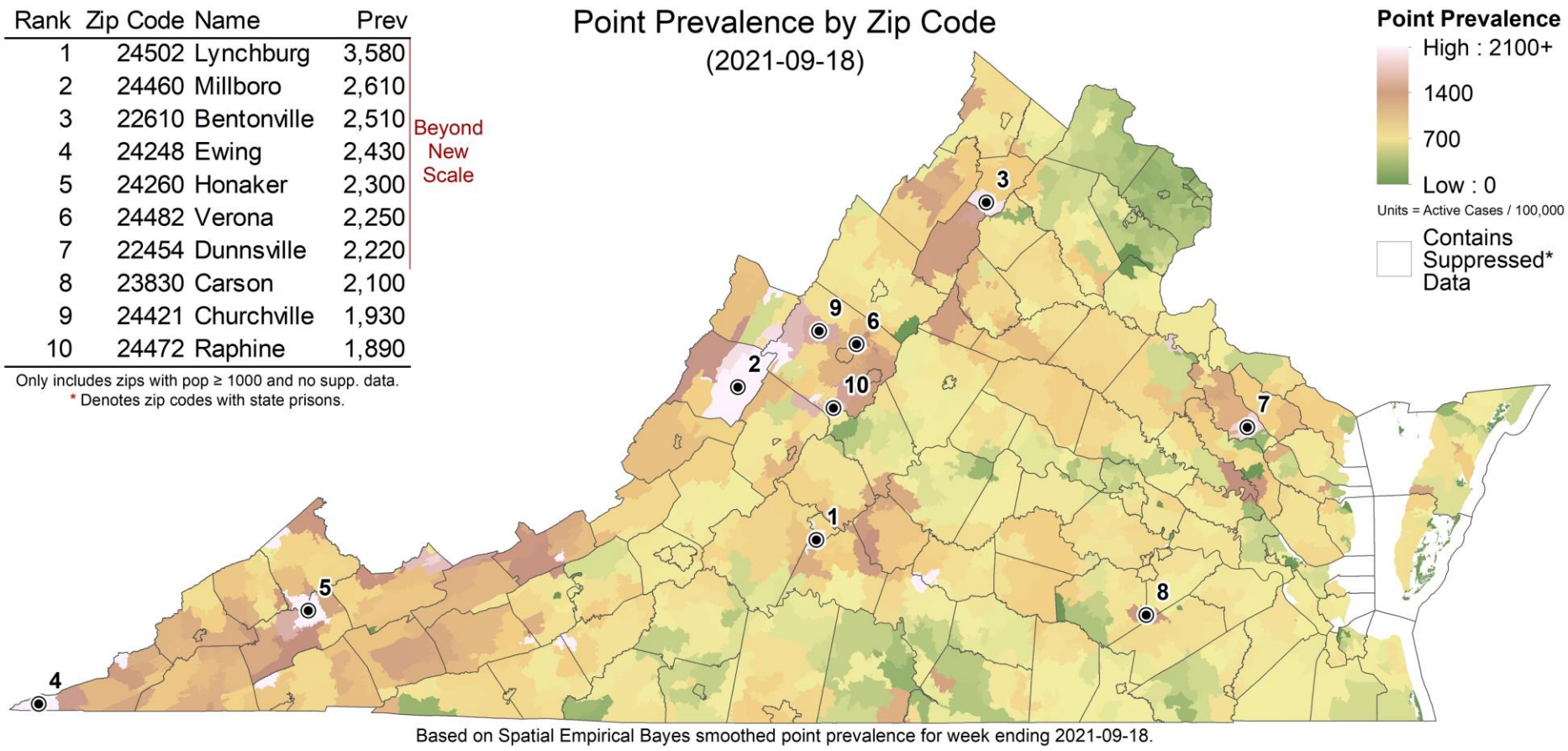
Case Rates in the last week by zip code

- 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	24502	Lynchburg	3,580
2	24460	Millboro	2,610
3	22610	Bentonville	2,510
4	24248	Ewing	2,430
5	24260	Honaker	2,300
6	24482	Verona	2,250
7	22454	Dunnsville	2,220
8	23830	Carson	2,100
9	24421	Churchville	1,930
10	24472	Raphine	1,890

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 2021-09-18.

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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)

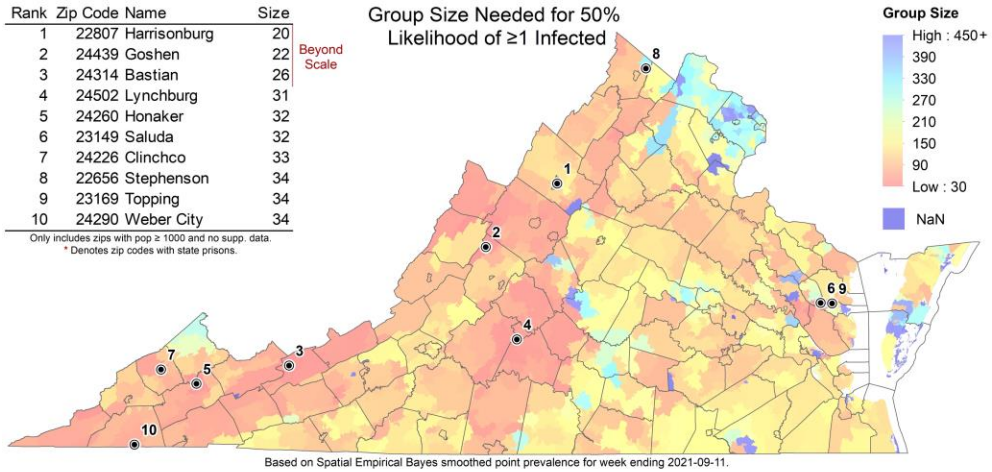
- **Group Size**: Assumes 2 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey), and shows minimum size of a group with a 50% chance an individual is infected by zip code (eg in a group of 19 in Lynchburg, there is a 50% chance someone will be infected)

From Last Week

Rank	Zip Code	Name	Size
1	22807	Harrisonburg	20
2	24439	Goshen	22
3	24314	Bastian	26
4	24502	Lynchburg	31
5	24260	Honaker	32
6	23149	Saluda	32
7	24226	Clinchco	33
8	22656	Stephenson	34
9	23169	Topping	34
10	24290	Weber City	34

Beyond Scale

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

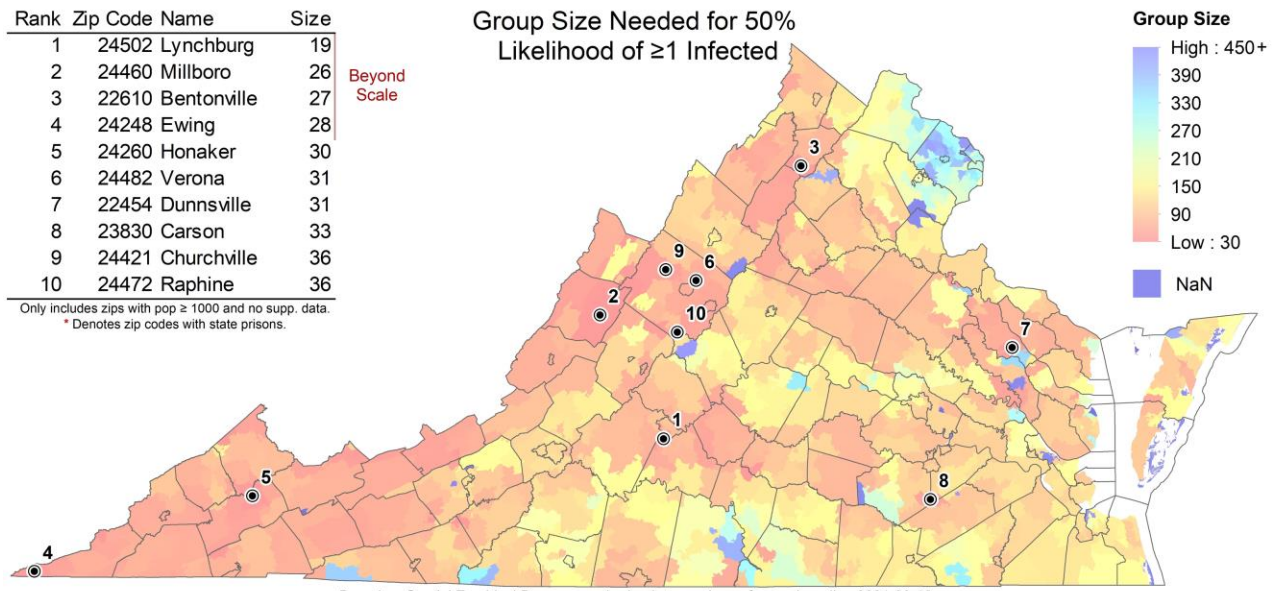


Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-09-11.

Rank	Zip Code	Name	Size
1	24502	Lynchburg	19
2	24460	Millboro	26
3	22610	Bentonville	27
4	24248	Ewing	28
5	24260	Honaker	30
6	24482	Verona	31
7	22454	Dunnsville	31
8	23830	Carson	33
9	24421	Churchville	36
10	24472	Raphine	36

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 2021-09-18.

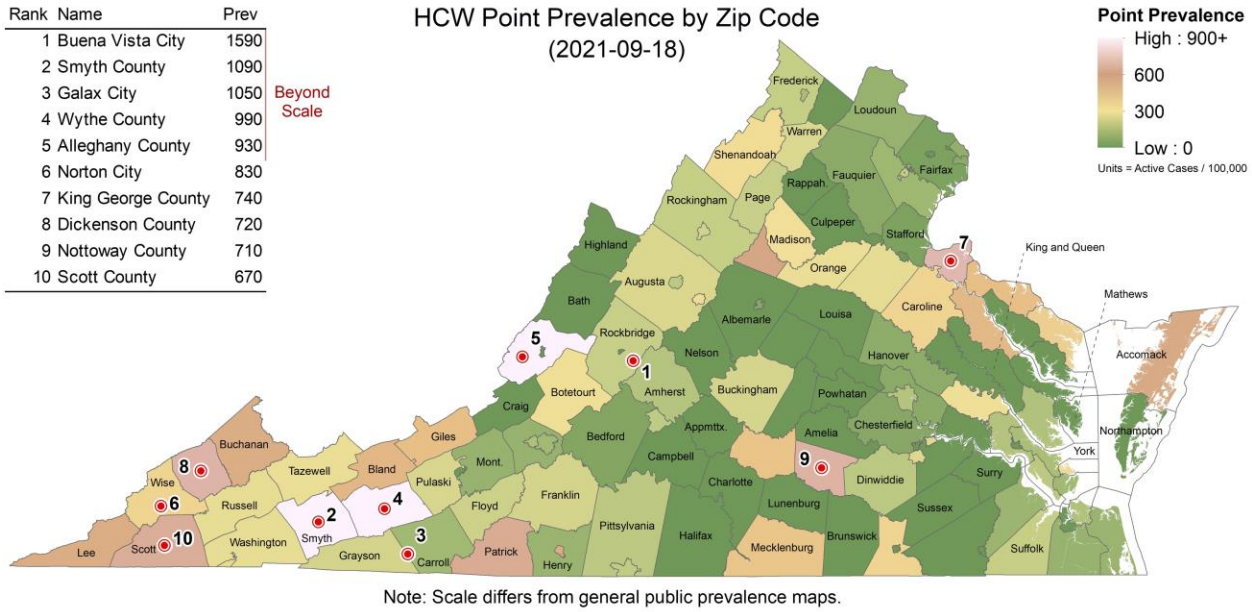
HCW Prevalence

- **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 Buena Vista City and far southwest (Wythe County to Wise County)
- **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	Buena Vista City	1590
2	Smyth County	1090
3	Galax City	1050
4	Wythe County	990
5	Alleghany County	930
6	Norton City	830
7	King George County	740
8	Dickenson County	720
9	Nottoway County	710
10	Scott County	670

Beyond Scale

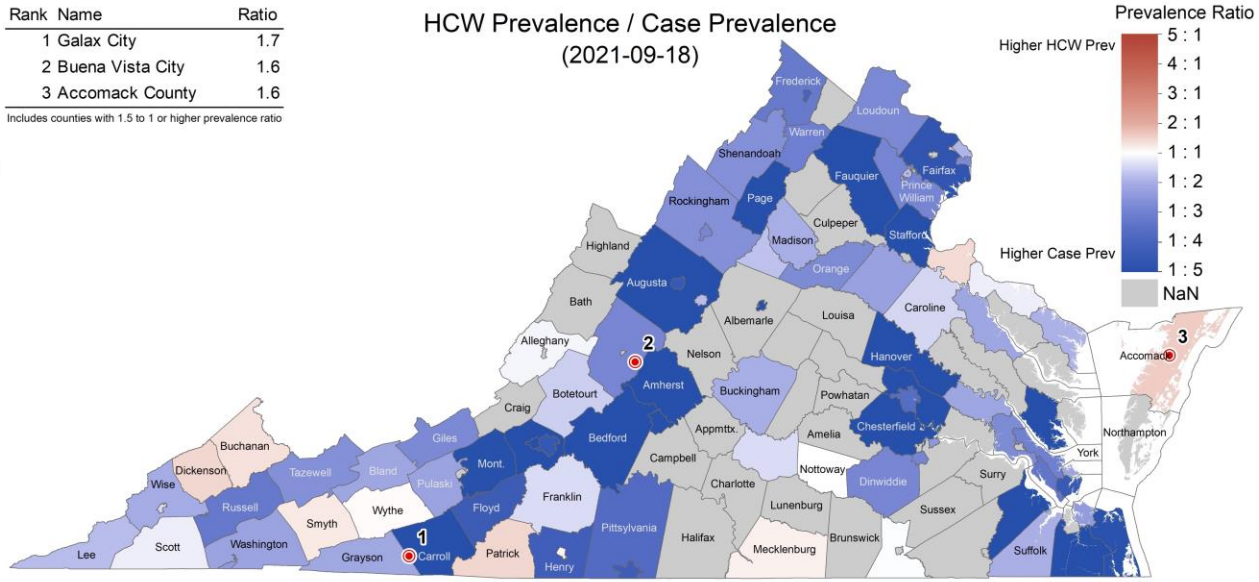


Note: Scale differs from general public prevalence maps.

HCW to Public Prevalence Ratio

Rank	Name	Ratio
1	Galax City	1.7
2	Buena Vista City	1.6
3	Accomack County	1.6

Includes counties with 1.5 to 1 or higher prevalence ratio



Current Hot-Spots

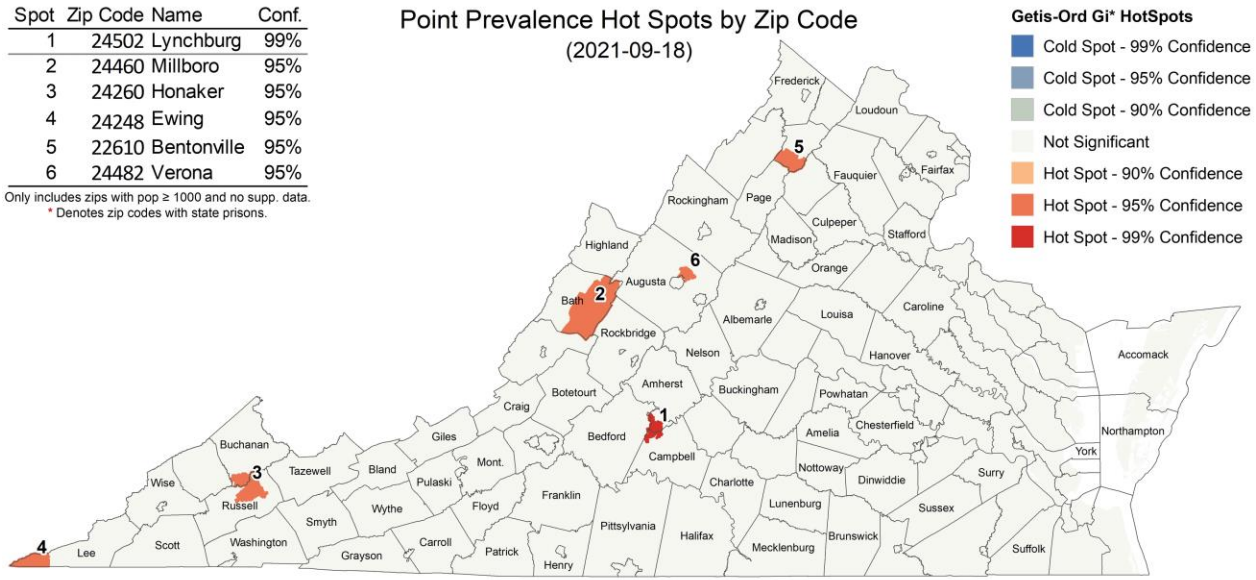
Case rates that are significantly different from neighboring areas or model projections

- **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

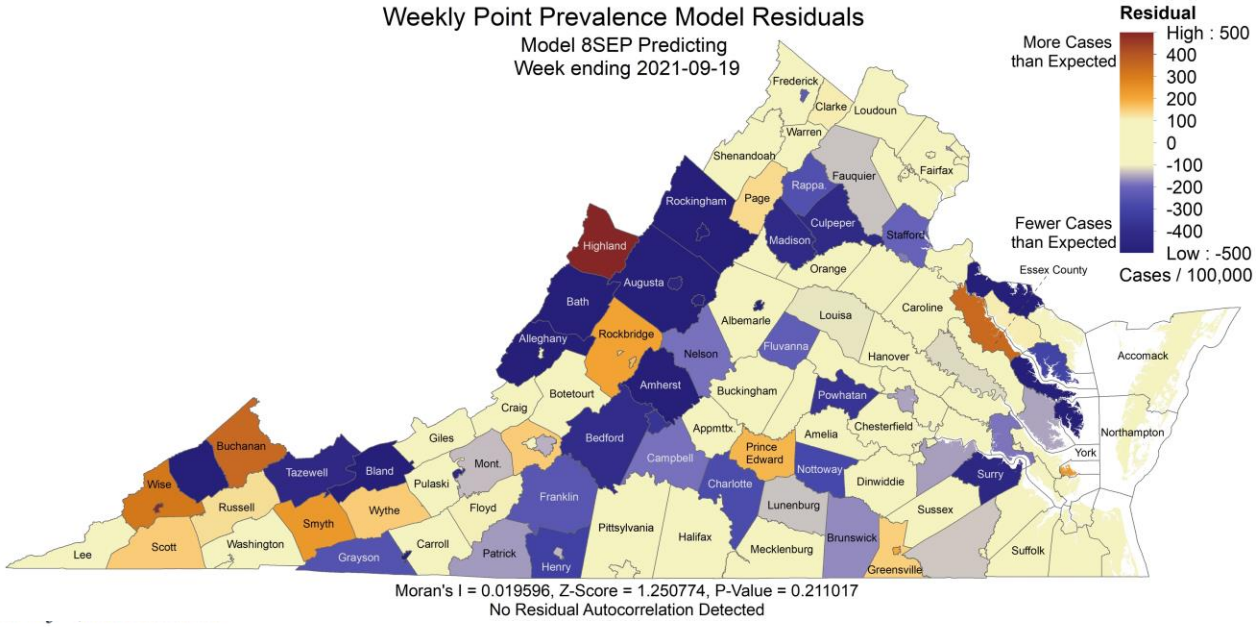
Spatial Hotspots

Spot	Zip Code	Name	Conf.
1	24502	Lynchburg	99%
2	24460	Millboro	95%
3	24260	Honaker	95%
4	24248	Ewing	95%
5	22610	Bentonville	95%
6	24482	Verona	95%

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



Clustered Temporal Hotspots



Model Update – Adaptive Fitting

Adaptive Fitting Approach

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

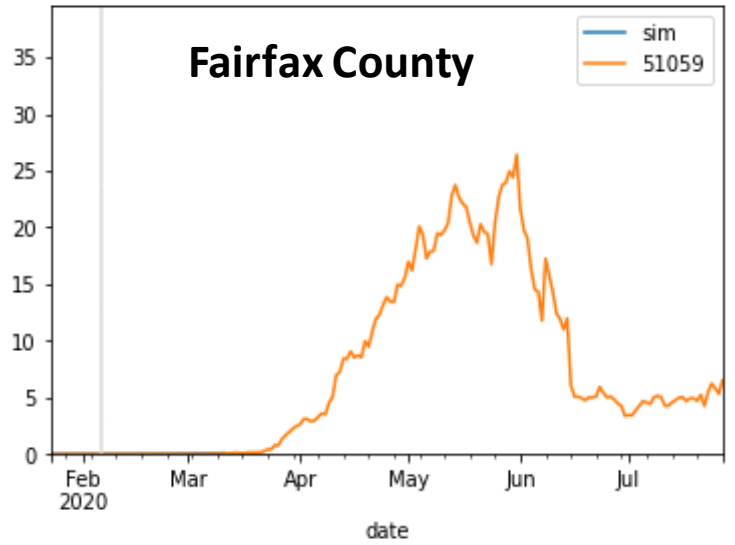
- Allows history to be precisely captured, and used to guide bounds on projections

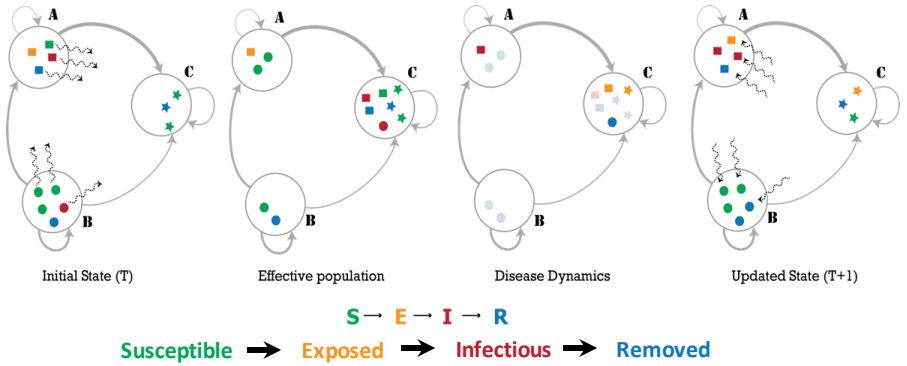
Model: An alternative use of the same meta-population model, PatchSim

- 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:

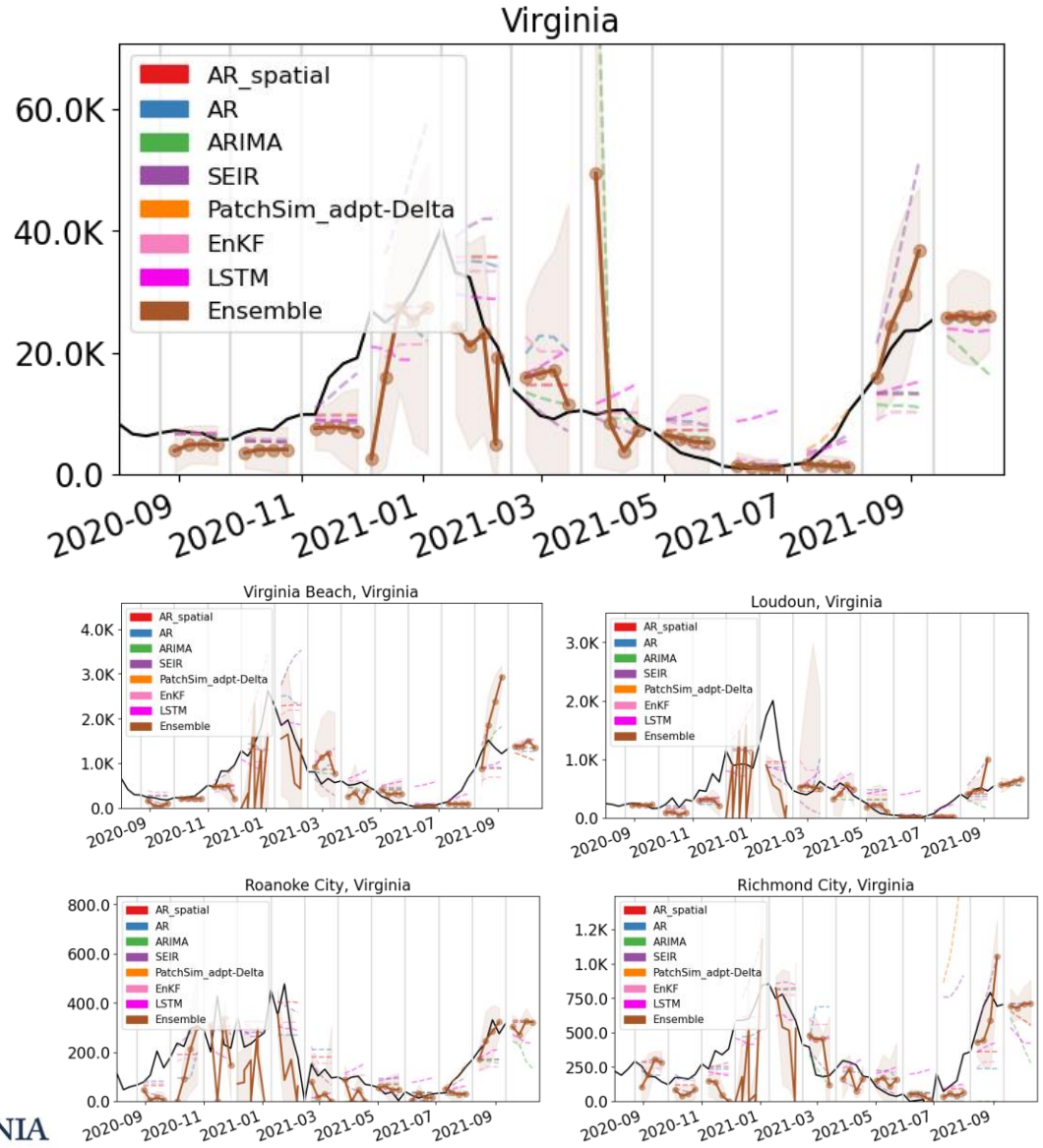
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

<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.



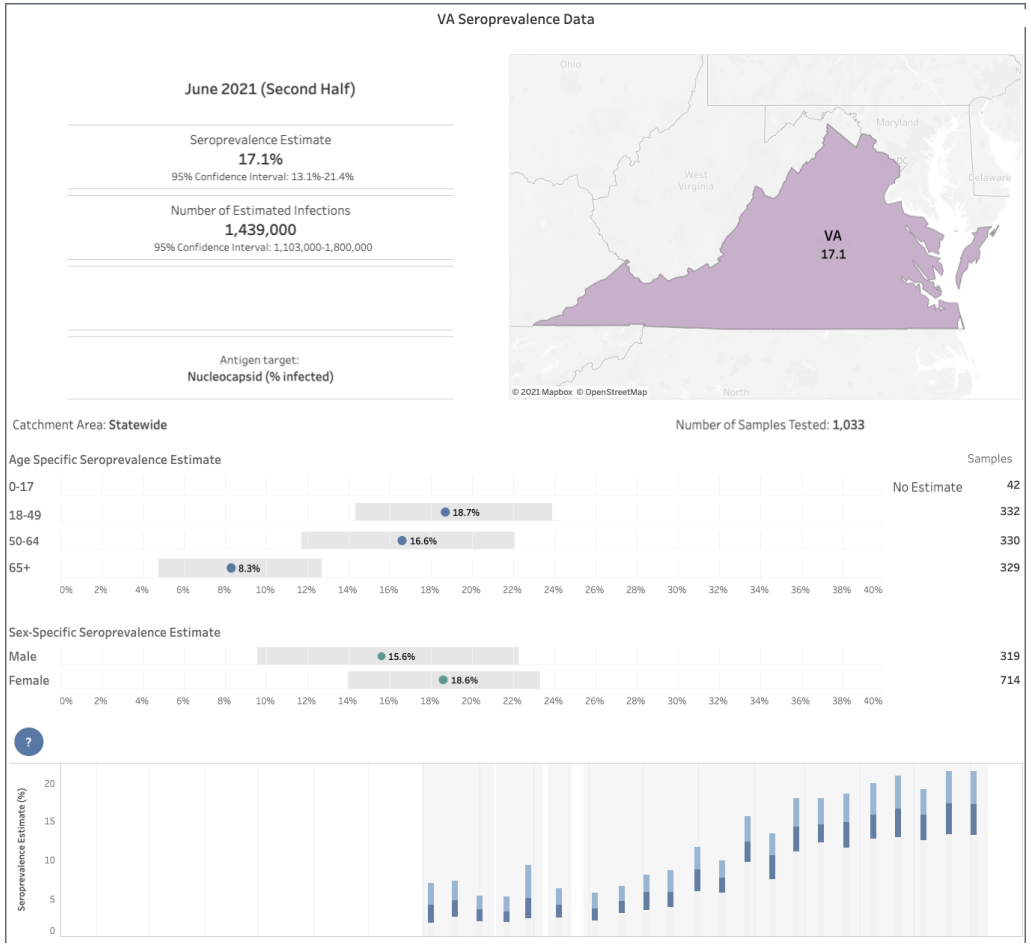
Seroprevalence updates to model design

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)

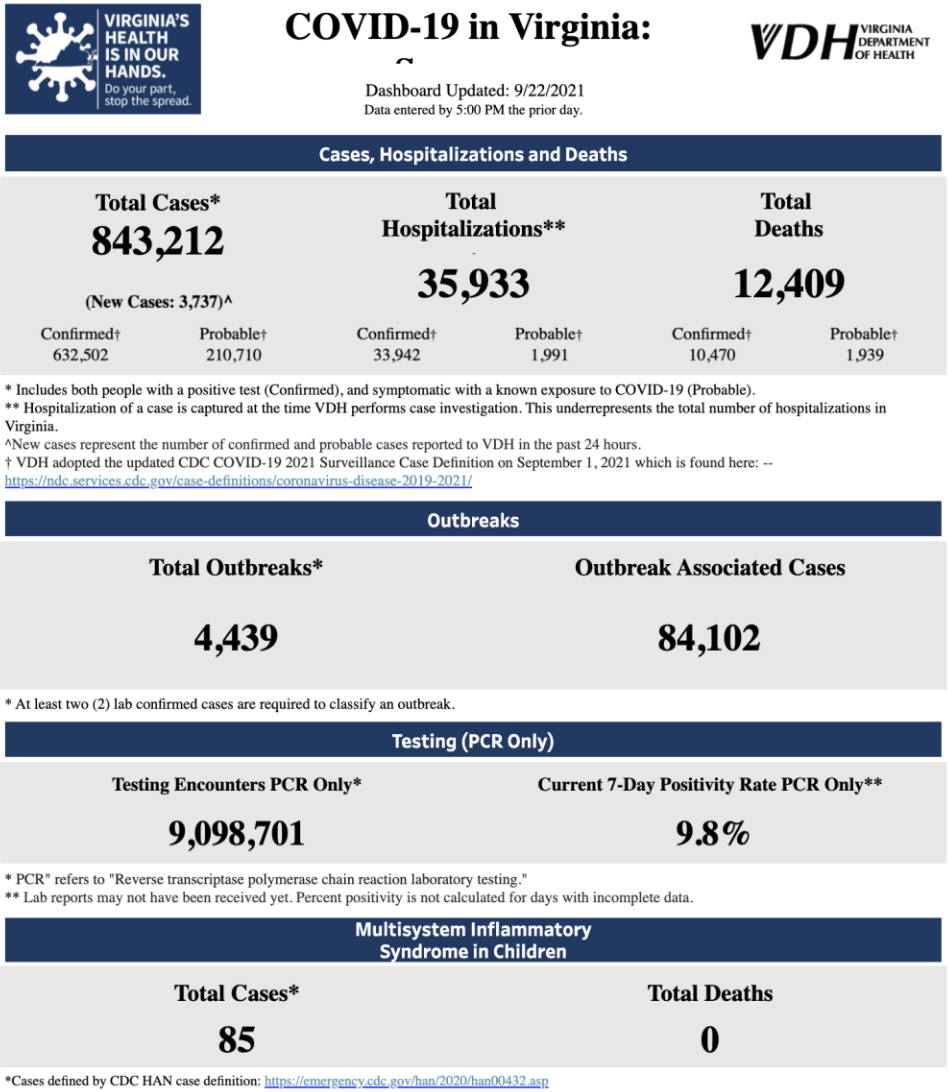
- Thus for 2x there are 2 total infections in the population for every confirmed case recently
- This measure now fully tracks the estimated ascertainment over time
- Uncertainty design has been shifted to these bounds (previously higher ascertainments as was consistent earlier in the pandemic were being 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 14 days of observed cases and first week of ensemble's forecast used**
  - Outliers removed based on variances in the previous 3 weeks
  - 2 week interpolation to smooth transitions in rapidly changing trajectories
- **Outcomes**: Data driven by shift and ratio that has least error in last month of observations
  - Hospitalizations: 3 days from confirmation, 6.8% of cases hospitalized
  - Deaths: 11 days from confirmation, 1.45% of cases die



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

COVID-19 in Virginia:

VDH VIRGINIA DEPARTMENT OF HEALTH

Dashboard Updated: 9/22/2021
Data entered by 5:00 PM the prior day.

Cases, Hospitalizations and Deaths

Total Cases*	Total Hospitalizations**	Total Deaths
843,212	35,933	12,409
(New Cases: 3,737)^		
Confirmed† 632,502 / Probable† 210,710	Confirmed† 33,942 / Probable† 1,991	Confirmed† 10,470 / Probable† 1,939

* 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 2021 Surveillance Case Definition on September 1, 2021 which is found here: -- https://ndc.services.cdc.gov/case-definitions/coronavirus-disease-2019-2021/

Outbreaks

Total Outbreaks*	Outbreak Associated Cases
4,439	84,102

* 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**
9,098,701	9.8%

* 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
85	0

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

Accessed 9:15am September 22, 2021
https://www.vdh.virginia.gov/coronavirus/

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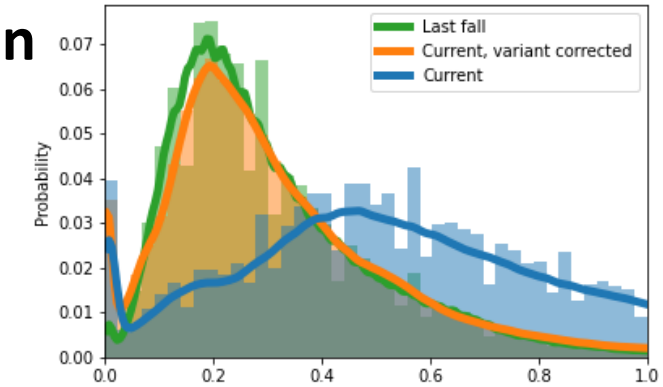
Scenarios – Transmission Conditions

- 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-FallWinter2020:** Starting this week the core drivers of transmission from Sept 2020 – Feb 2021 are coarsely replayed but boosted to account for Delta's increased transmissibility
  - **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

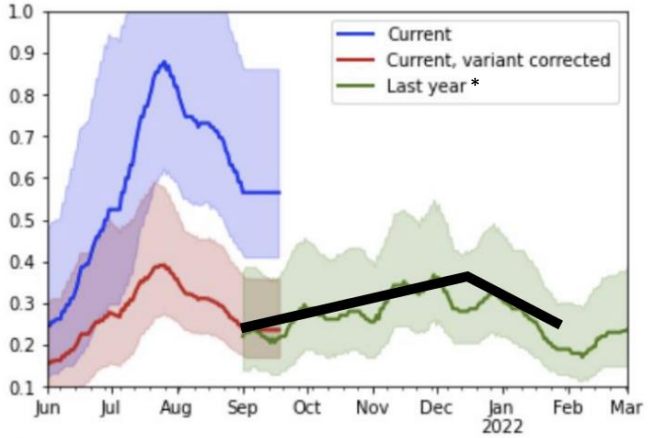
Scenarios – FallWinter2020 Description

September 2020 – February 2021 saw a strong wave of transmission

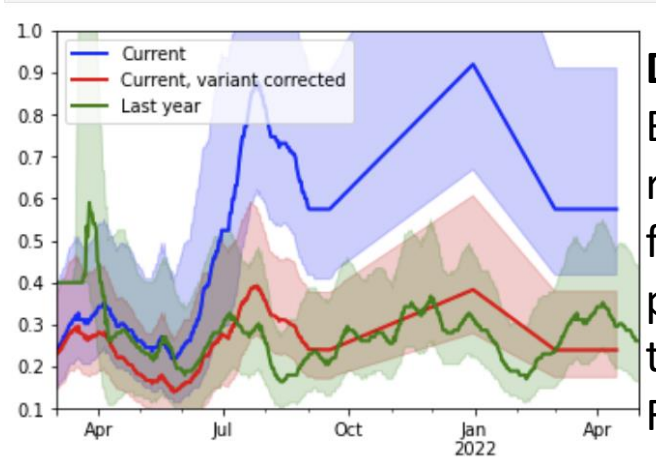


- We analyze previous Fall-Winter's wave vs. current Delta driven wave and observe surprising similarities
  - The distribution of fitted model transmissibility is nearly identical between these periods when corrected for Delta's increased transmissibility
- **FallWinter2020** tries to capture the "transmission drivers" from the past and use them as if they were to occur again this season but with Delta variant (compared to ancestral)
  - Use the above analysis of fitted model transmissibilities from Sept 2020 – Feb 2021 to guide the future transmissibility from Sept 2021 through Feb 2022, but add the enhanced transmissibility of Delta back in

Fitting:
Black line represents the coarsely fitted base transmissibility



* "Last year" is transplanted into 2021-22



Delta enhanced:
Blue trajectory represents current fitted and then projected transmissibility in FallWinter2020

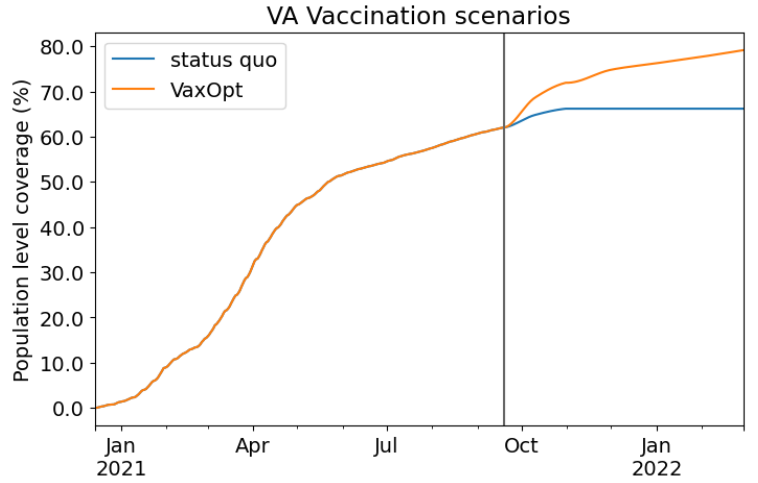
Scenarios – Vaccination Conditions

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	109.7K	109.7K
2021-01-31	648.5K	648.5K
2021-02-28	561.6K	561.6K
2021-03-31	1.3M	1.3M
2021-04-30	1.2M	1.2M
2021-05-31	578.3K	578.3K
2021-06-30	252.2K	252.2K
2021-07-31	261.4K	261.4K
2021-08-31	270.4K	270.4K
2021-09-30	221.6K	406.0K
2021-10-31	191.5K	562.3K
2021-11-30	0.0	240.3K
2021-12-31	0.0	125.0K
2022-01-31	0.0	122.9K
2022-02-28	0.0	122.7K
2022-03-31	0.0	4.7K

Cumulative

Date	status quo	VaxOpt
2020-12-31	109.7K	109.7K
2021-01-31	758.3K	758.3K
2021-02-28	1.3M	1.3M
2021-03-31	2.6M	2.6M
2021-04-30	3.8M	3.8M
2021-05-31	4.4M	4.4M
2021-06-30	4.6M	4.6M
2021-07-31	4.9M	4.9M
2021-08-31	5.2M	5.2M
2021-09-30	5.4M	5.6M
2021-10-31	5.6M	6.1M
2021-11-30	5.6M	6.4M
2021-12-31	5.6M	6.5M
2022-01-31	5.6M	6.6M
2022-02-28	5.6M	6.8M
2022-03-31	5.6M	6.8M

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-SurgeControl	25%	SQ	Transmission rates in the next month reduced through increased control from non-pharmaceutical interventions, with status quo vax and Delta
Adaptive-FallWinter2020	FallWinter 2002	SQ	Transmission rates coarsely follow the rates from last September through this February but are boosted by Delta's enhanced transmissibility

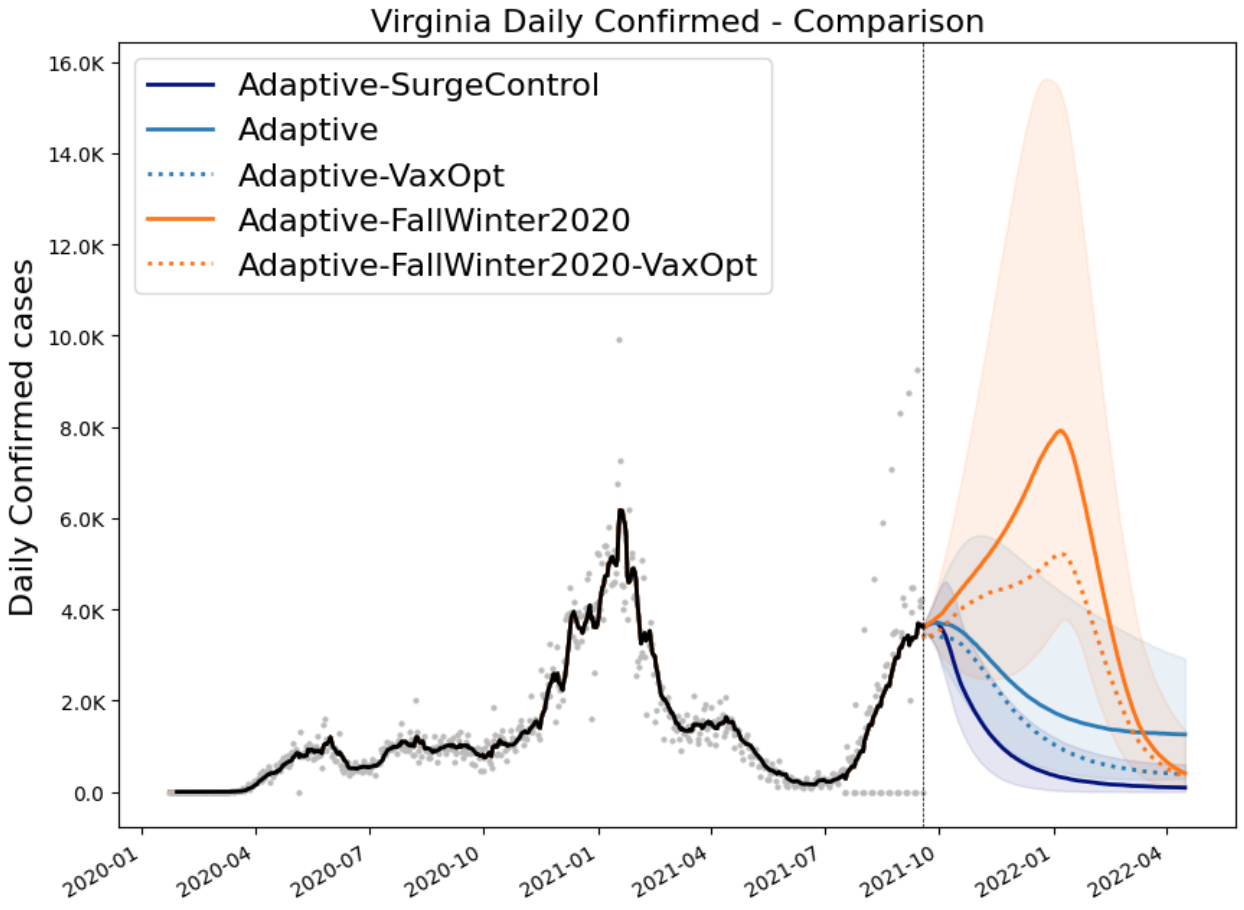
Transmission Controls:
C = Current levels persist into the future
25% = Transmission rates are reduced by 25% with a gradual introduction, concluding in 4 weeks
FallWinter2020 = Transmission rates from Sept 2020 – Feb 2021 are coarsely replayed but boosted by Delta's increased transmissibility

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

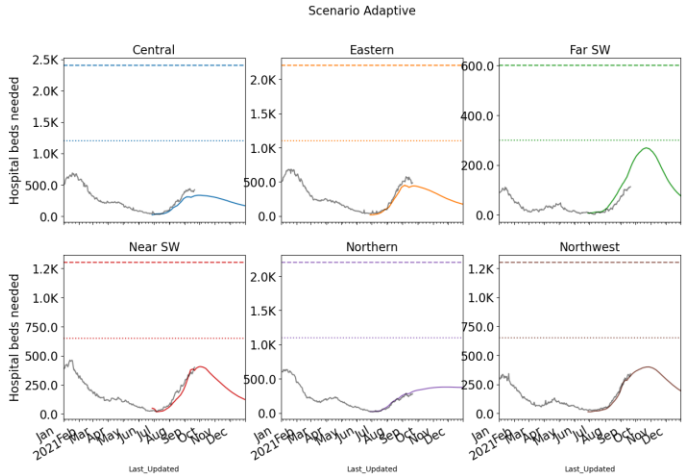
Model Results

Outcome Projections

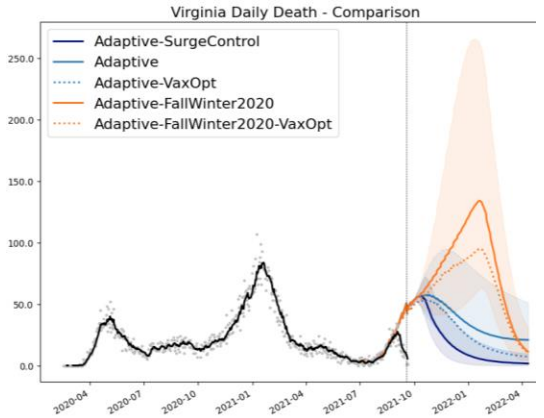
Confirmed cases



Estimated Hospital Occupancy

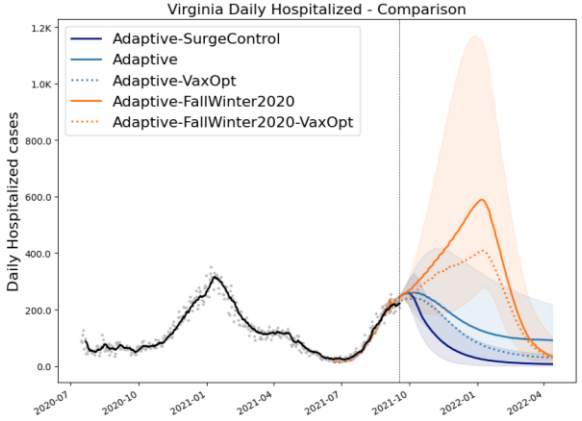


Daily Deaths



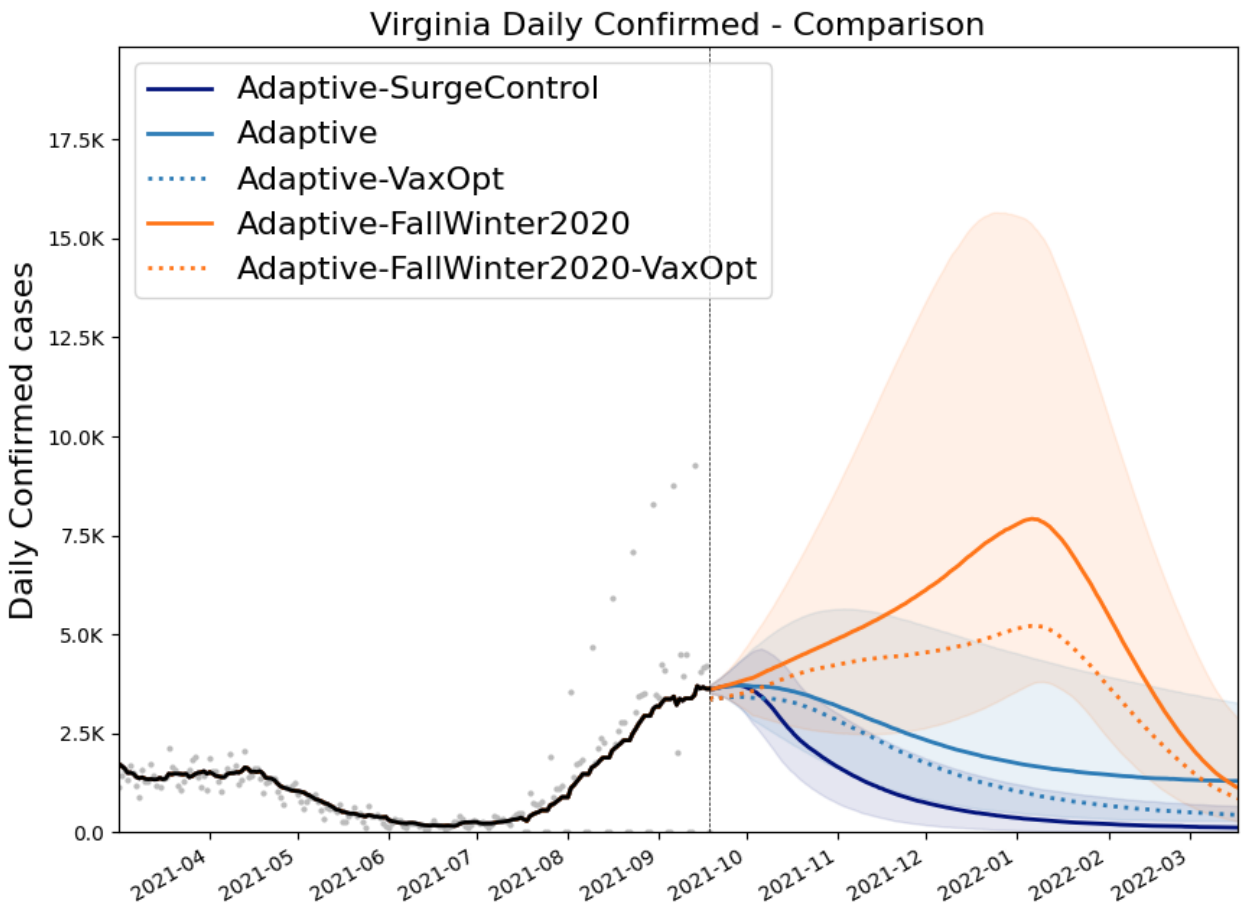
Death ground truth from VDH "Event Date" data, most recent dates are not complete

Daily Hospitalized

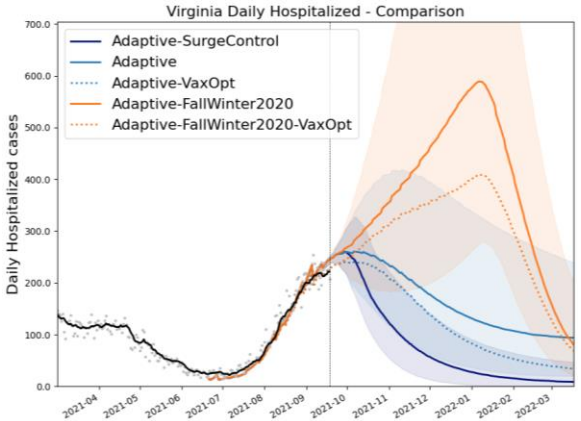


Outcome Projections – Closer Look

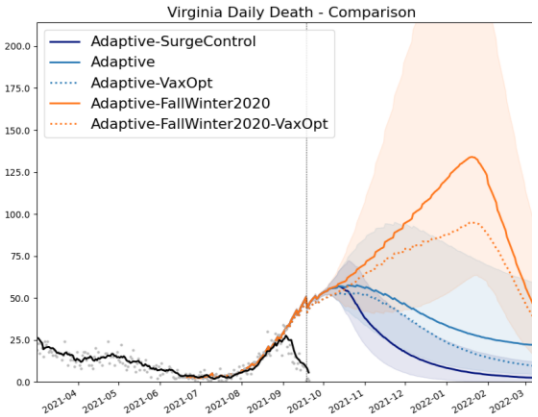
Confirmed cases



Daily Hospitalized



Daily Deaths



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

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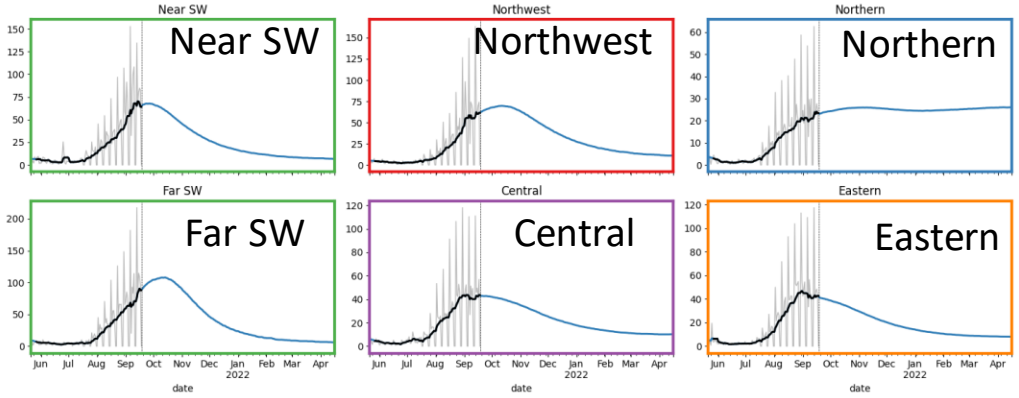
District Level Projections: Adaptive

Projections by Region

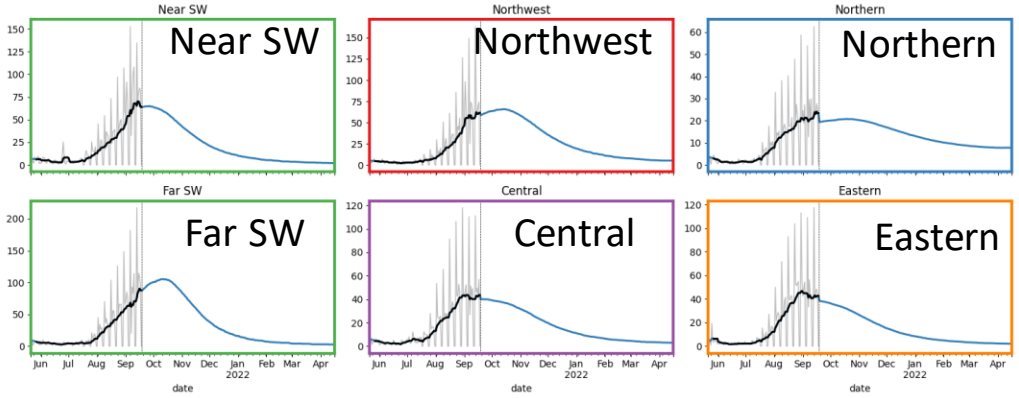


Projections by District

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

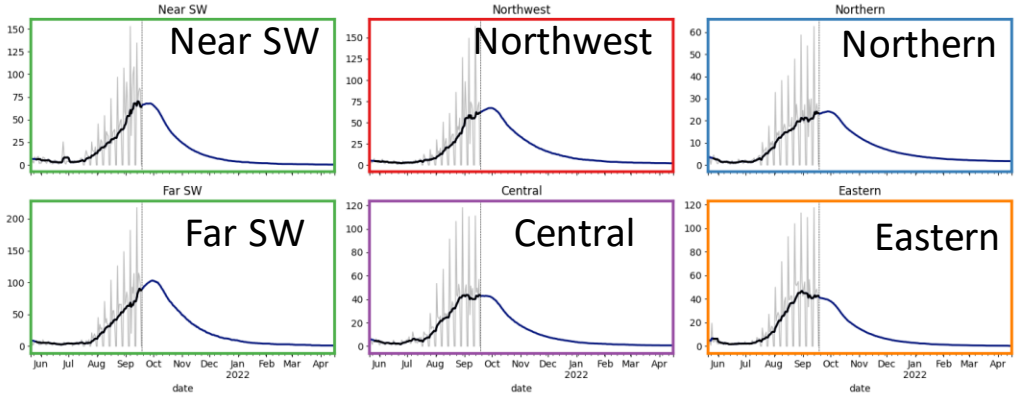


Projections by District

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

District Level Projections: Adaptive-SurgeControl

Projections by Region

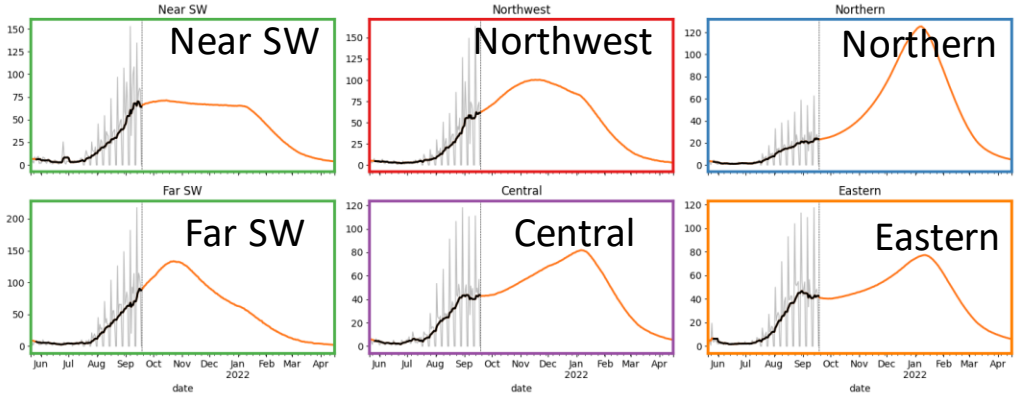


Projections by District

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

District Level Projections: Adaptive-FallWinter2020

Projections by Region

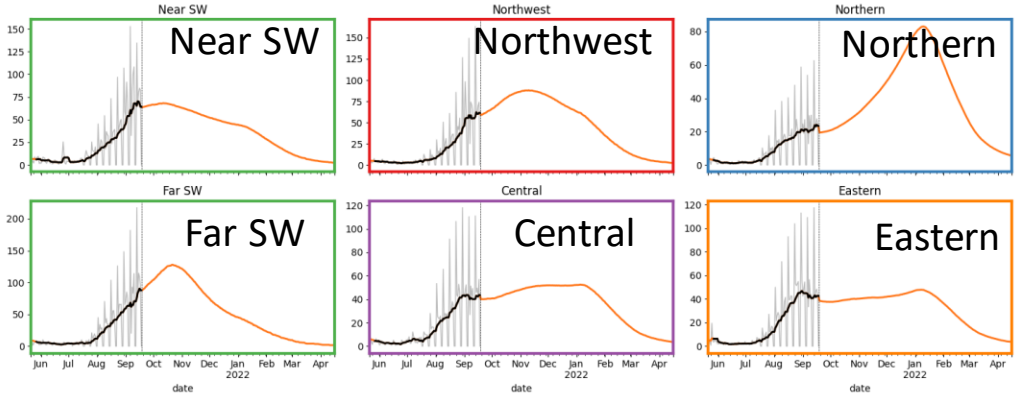


Projections by District

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

District Level Projections: Adaptive-FallWinter2020-VaxOpt

Projections by Region



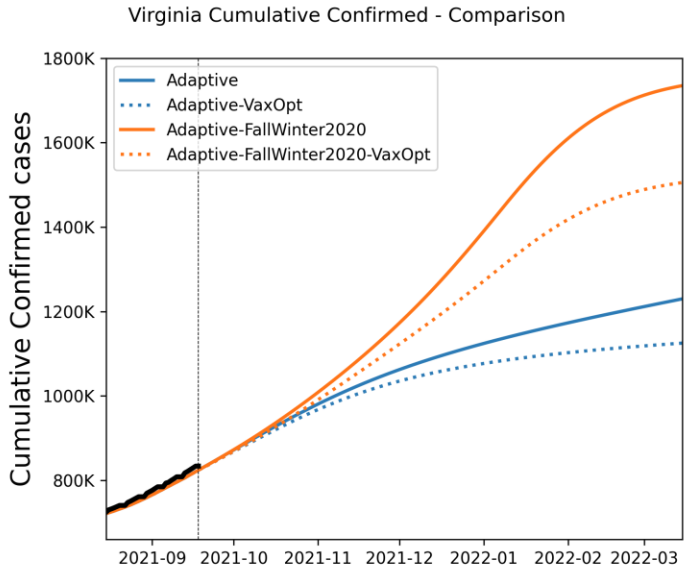
Projections by District

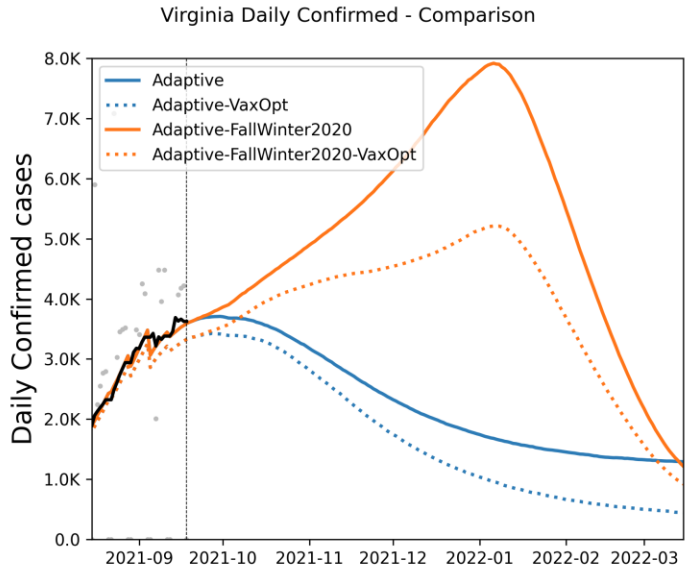
Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

Impact of expanded vaccine acceptance

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

- Even with declining transmission rates coming off of a Delta wave, expanded vax coverage can reduce case counts by ~140K, in addition to providing further resilience to future waves
- Expanded vaccination coverage including children can further curtail the impact of a Fall Winter Surge by up to ~240K cases

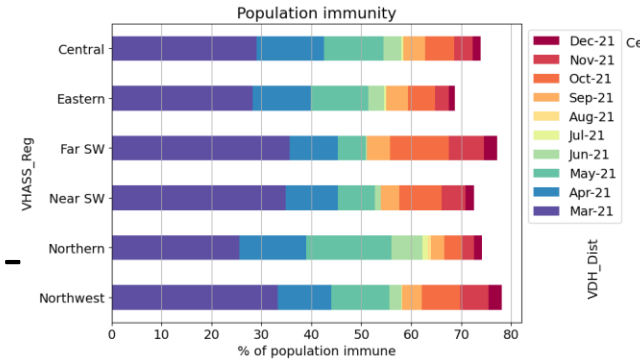


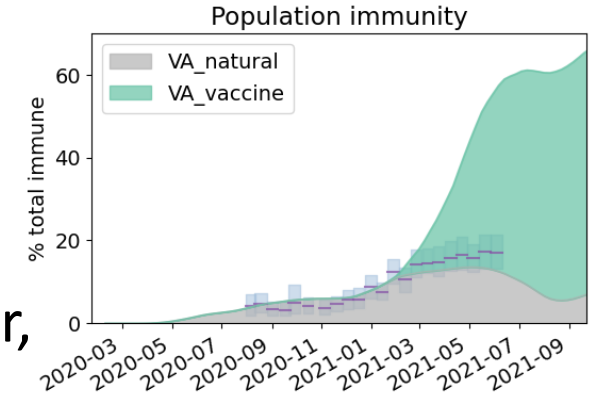


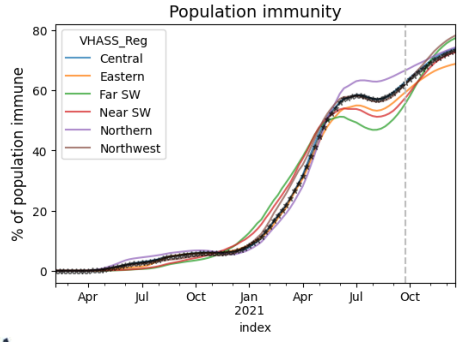
Virginia's Progress on Population Immunity

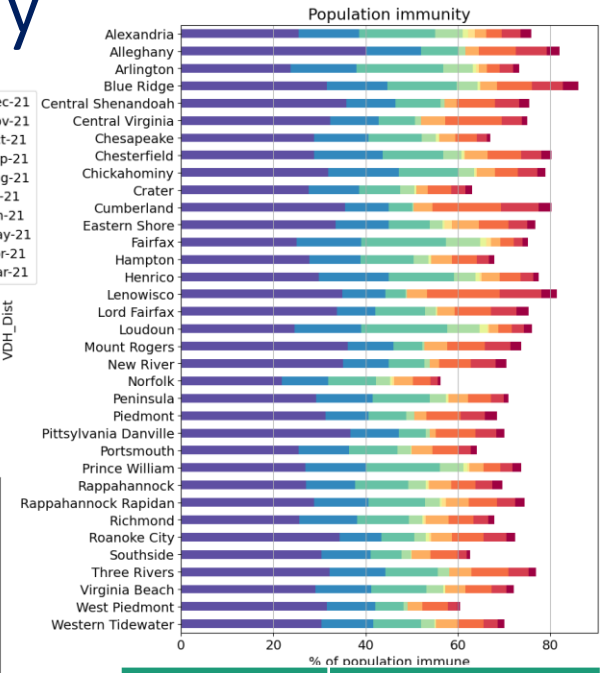
Natural Immunity and Vaccines combine to produce a population level of immunity

- 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	62%
Eastern	58%
Far SW	54%
Near SW	56%
Northern	66%
Northwest	61%
Virginia	61%

* As of Sept 19, 2021 (updated to account for entire population)

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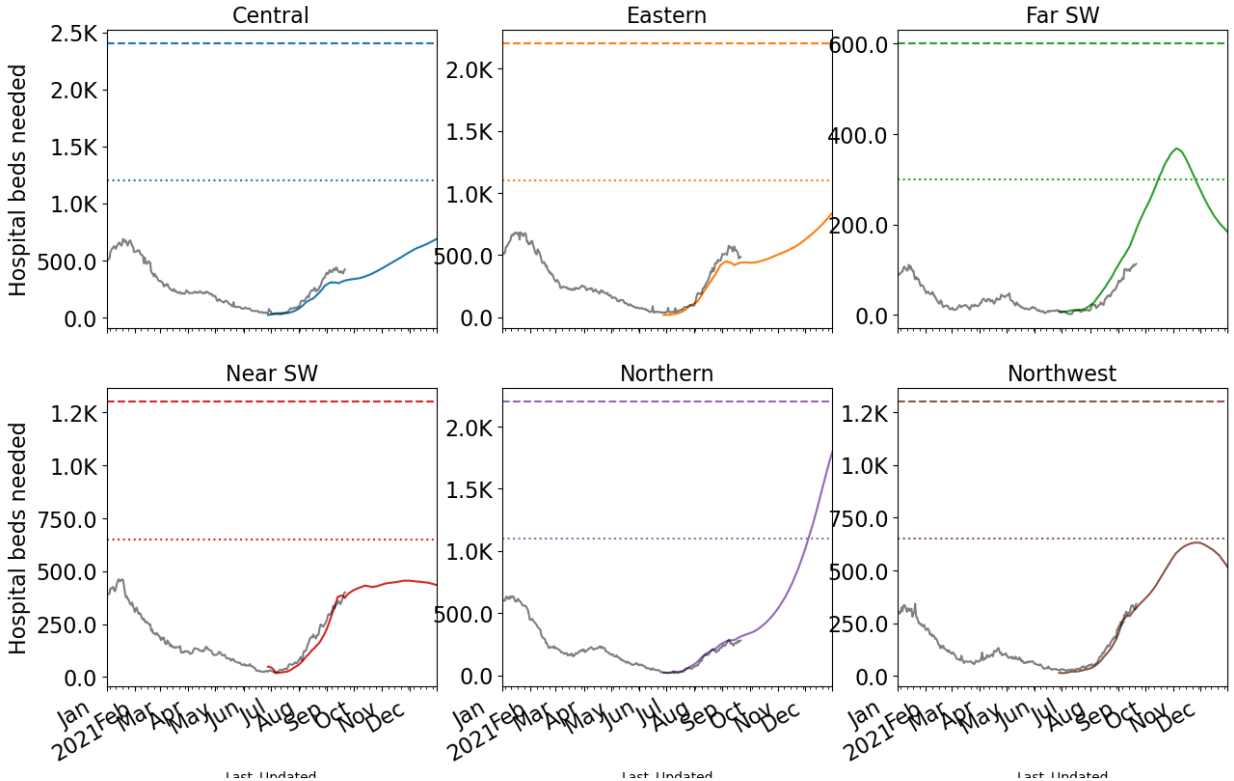
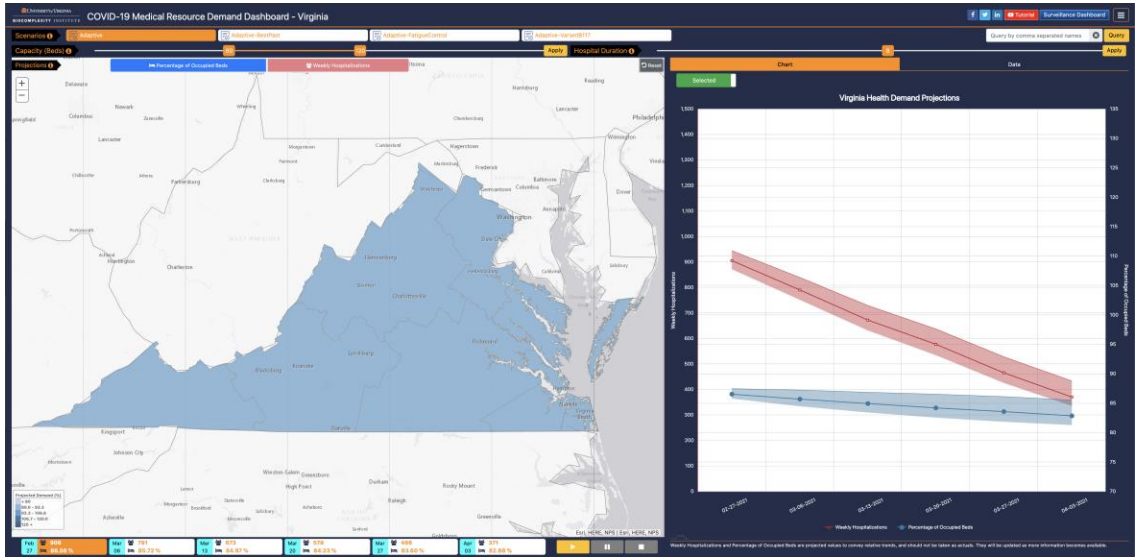
Hospital Demand and Bed Capacity by Region

Capacities* by Region – Adaptive FallWinter2020

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





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

Adaptive FallWinter2020 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 rate growth in Virginia has slowed, trends are very mixed across districts with majority also showing slow growth; case rates remain high as we may be cresting the peak of the Delta wave**
- VA 7-day mean daily incidence is slightly down to 42/100K from 43/100K; US is also slightly down to 48/100K (from 50/100K)
- Projections show a plateau and declining incidence in the near term, scenario based on last year's transmission drivers show that significant future case growth remains possible
- Recent updates:
  - Added FallWinter2020 scenario which replays the transmission drivers of last Fall-Winter season
  - Adjustment to higher levels of assumed immunity waning (natural and vaccine)

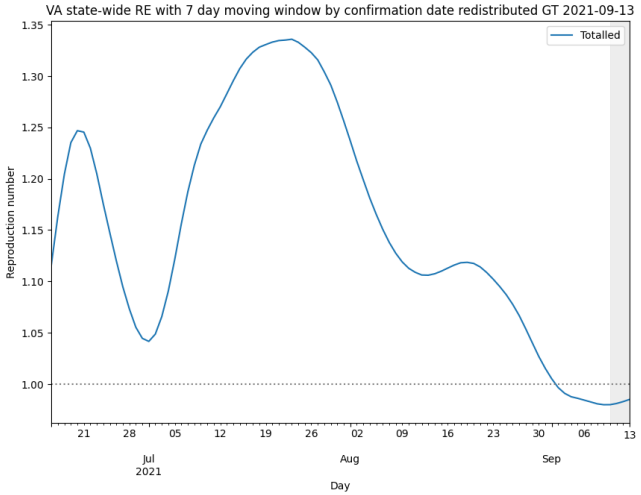
The situation continues to change. Models continue to be updated regularly.

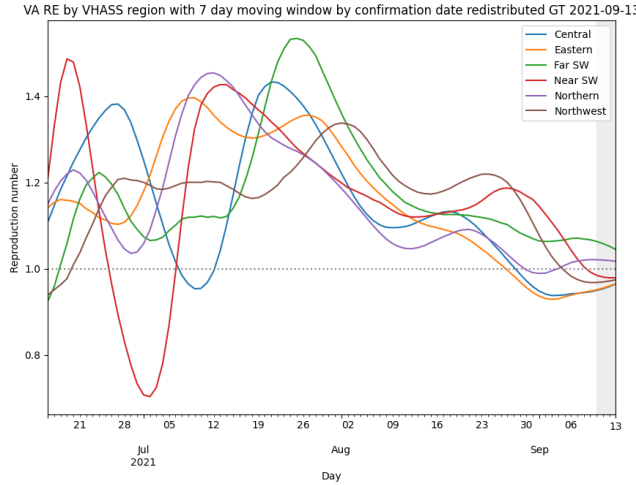
Additional Analyses

Estimating Daily Reproductive Number –
Redistributed weekend gap

Sept 13th Estimates

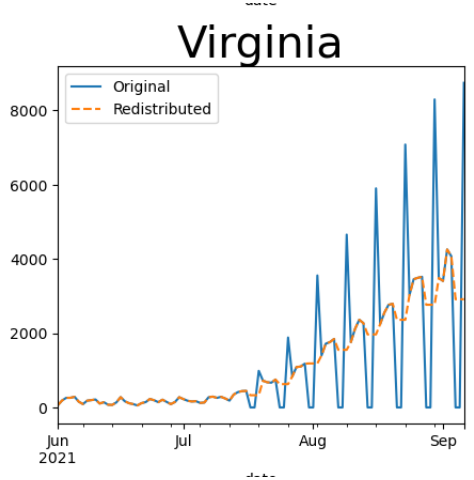
Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	0.984	-0.019
Central	0.942	0.034
Eastern	0.939	0.034
Far SW	1.070	0.134
Near SW	1.043	0.024
Northern	1.014	0.100
Northwest	0.983	0.001





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

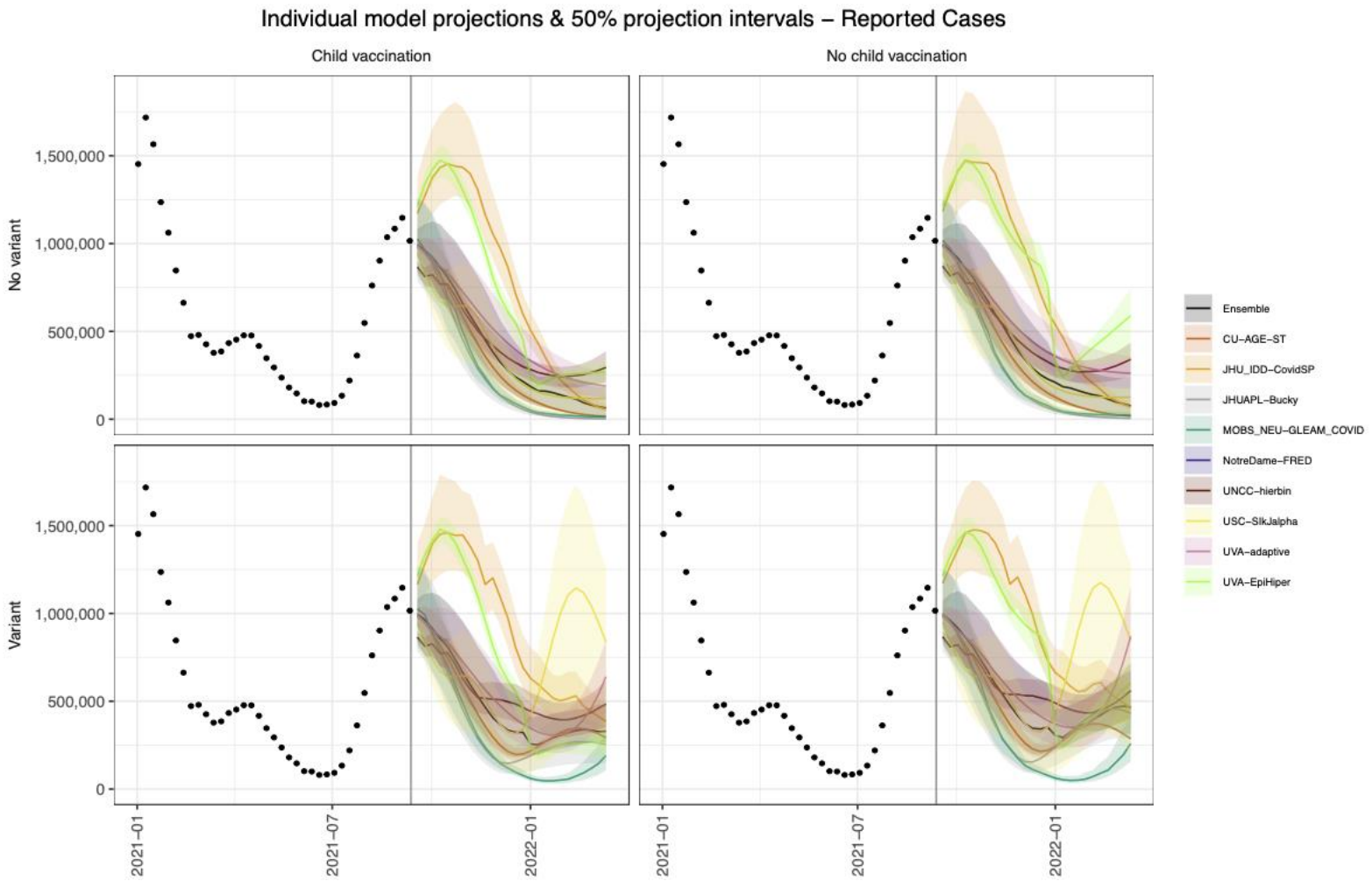
COVID-19 Scenario Modeling Hub

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 9 released to assist in support of 5-11 vax consideration (ACIP meeting Sept 22-23)
- Rounds 4-8 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 in 5-11 start in Nov

- Follows same rates as adolescents

Emerging Variant Impact (5% prevalence on Nov 15)

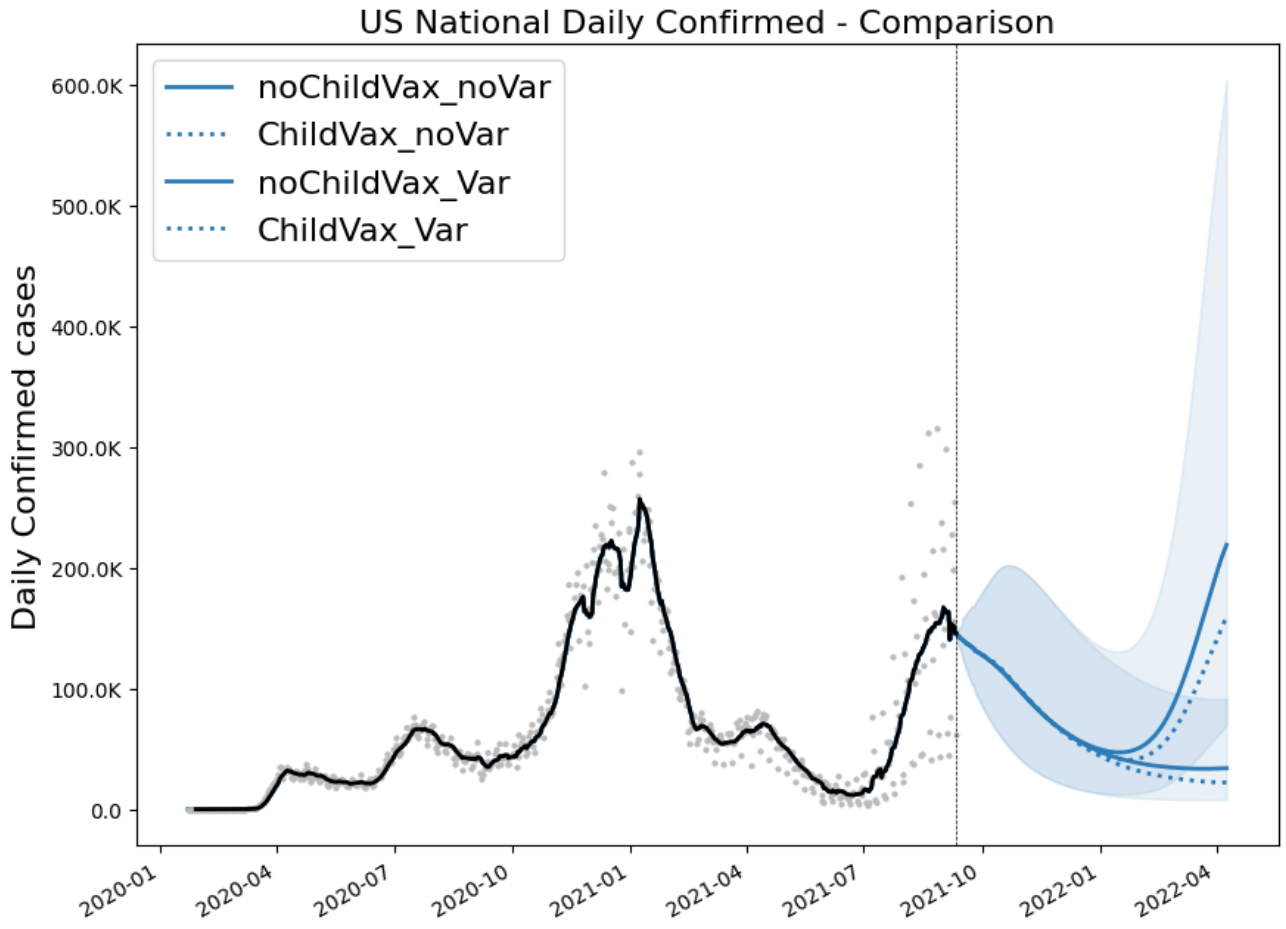
- 50% boost as it eventually predominates

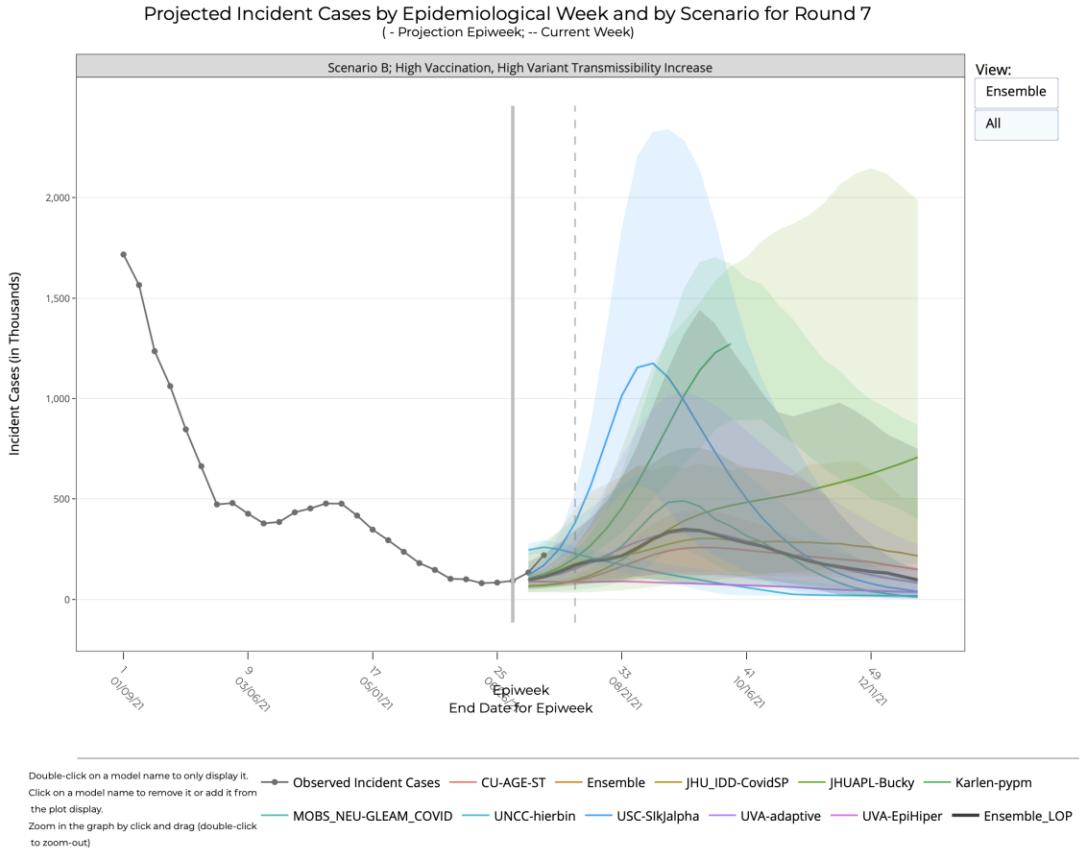
We consider a 2x2 scenario design, where childhood vaccination (5-11 years) is on the first axis, and a change in virus transmissibility is on the second axis. The second axis reflects a stress test, illustrating the potential impact of a new variant arising during the projection period:

	The same mix of variants circulate throughout the projection period. No change in virus transmissibility.	A more transmissible variant emerges, comprising 1% of circulating viruses on **Nov 15**. The new variant is **1.5X** as transmissible as viruses circulating at the beginning of the projection period.
Vaccination among 5-11yrs is approved and immunization begins on Nov 1. Each state's uptake rate reflects the percent coverage increases observed for 12-17-year-olds since distribution began on May 13.	A	C
No vaccination for children under 12	B	D

https://covid19scenariomodelinghub.org/viz.html

Modeling Hub – Round 9 Prelim Results

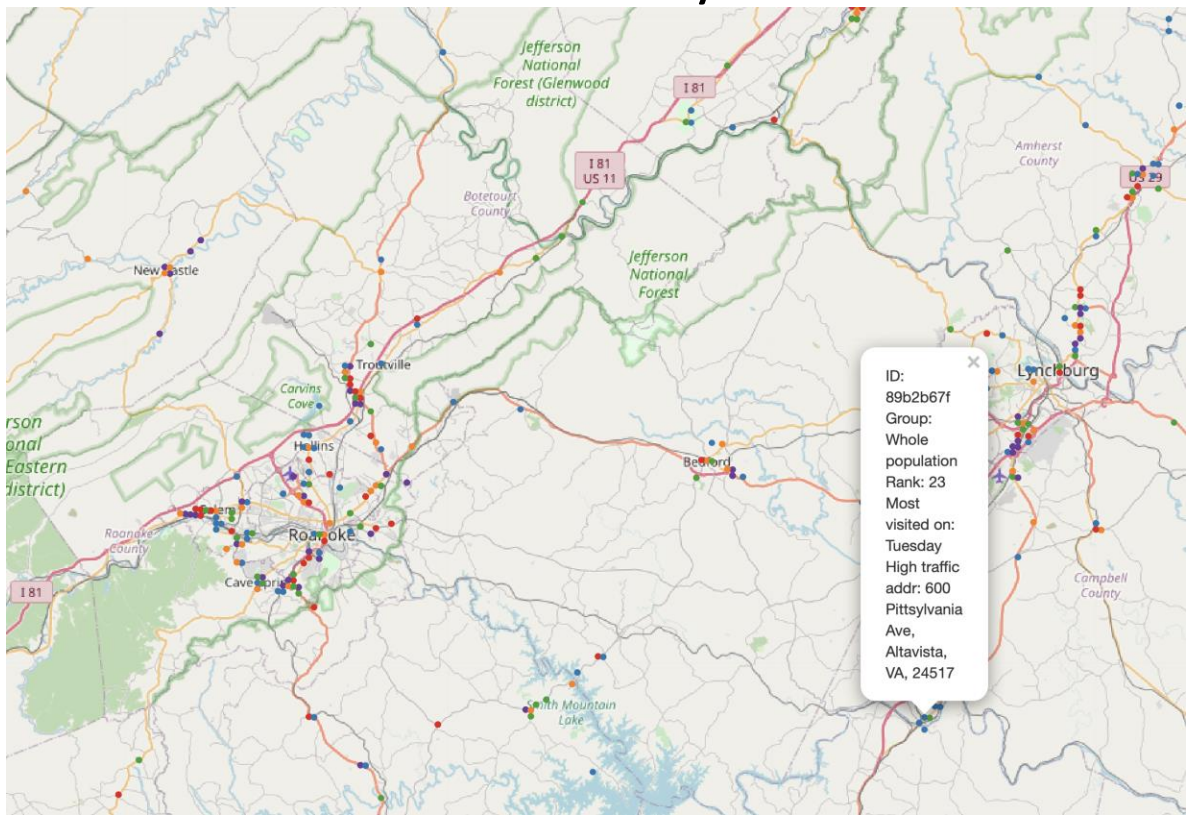




https://covid19scenariomodelinghub.org/viz.html

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

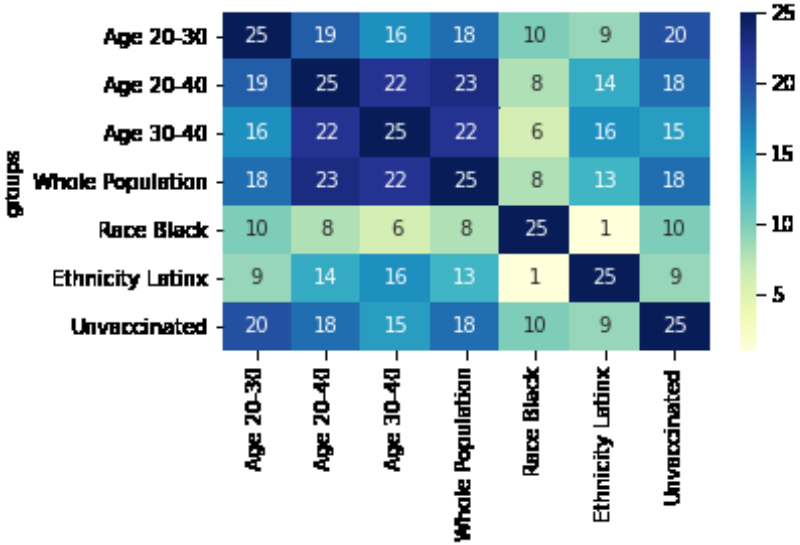
Goal: Provide frequently visited locations based on populations and vaccination levels one desires to reach

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

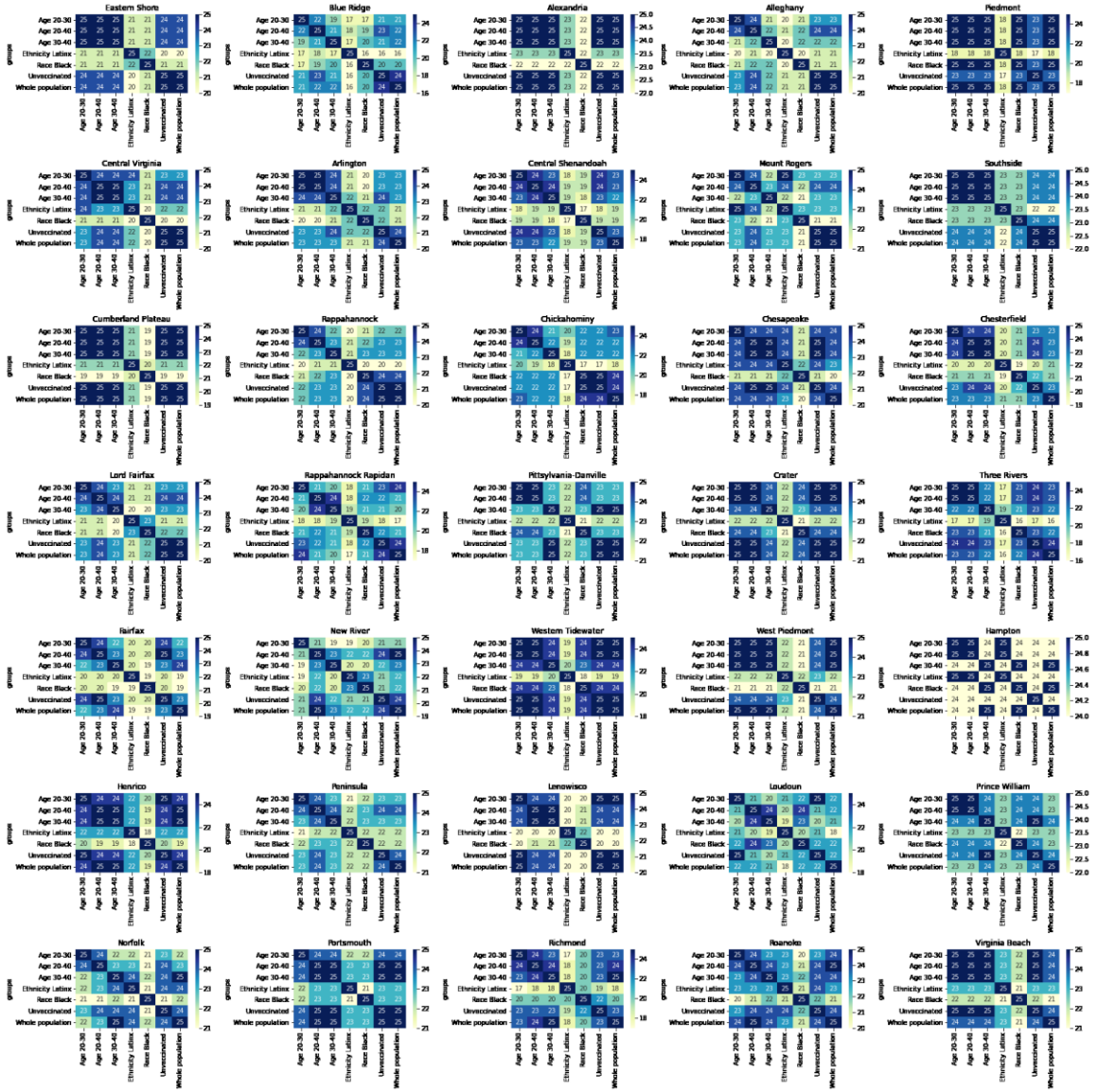
Data Recommended Mobile Vax Clinic Sites

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 gaps
- Districts have different overlap patterns

References

Venkatramanan, S., et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints." *PLoS Computational Biology* 15.9 (2019): e1007111.

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

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

Biocomplexity Institute. COVID-19 Surveillance Dashboard. https://nssac.bii.virginia.edu/covid-19/dashboard/

Google. COVID-19 community mobility reports. https://www.google.com/covid19/mobility/

Biocomplexity page for data and other resources related to COVID-19: https://covid19.biocomplexity.virginia.edu/

Questions?

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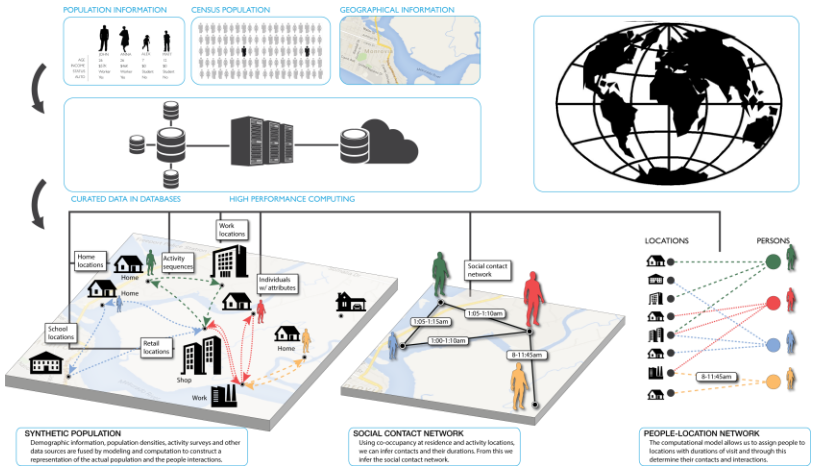
Supplemental Slides

Agent-based Model (ABM)

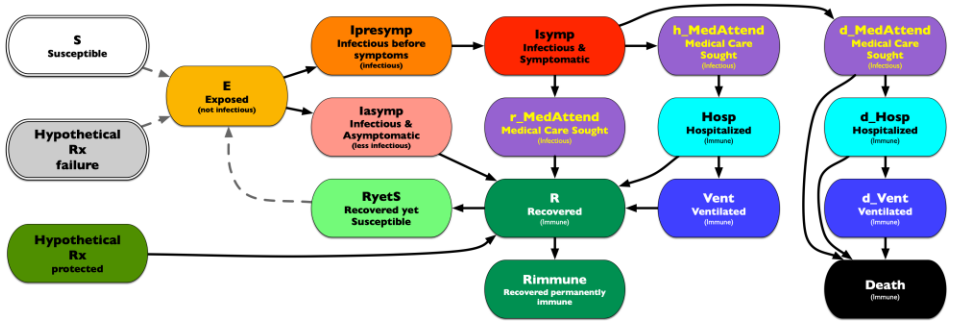
EpiHiper: Distributed network-based stochastic disease transmission simulations

- 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