Wastewater surveillance for COVID-19 forecasting

Promises and Pitfalls

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Biocomplexity Institute, University of Virginia

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Motivation & Challenges

Detecting novel variants

Morbidity and Mortality Weekly Report (*MMWR*)

Notes from the Field: Early Evidence of the SARS-CoV-2 B.1.1.529 (Omicron) Variant in Community Wastewater — United States, November–December 2021

Weekly / January 21, 2022 / 71(3);103–105

Amy E. Kirby, PhD[1]; Rory M. Welsh, PhD[1]; Zachary A. Marsh, MPH[1]; Alexander T. Yu, PhD[2]; Duc J. Vugia, MD[2]; Alexandria B. Boehm, PhD[3]; Marlene K. Wolfe, PhD[4]; Bradley J. White[5]; Shannon R. Matzinger, PhD[6]; Allison Wheeler, MSPH[6]; Laura Bankers, PhD[6]; Kevin Andresen, MPH[6]; Cristal Salatas, MSGH[6]; New York City Department of Environmental Protection; Devon A. Gregory, PhD[7,8,9]; Marc C. Johnson, PhD[7]; Monica Trujillo, PhD[10]; Sherin Kannoly, PhD[8]; Davida S. Smyth, PhD[11]; John J. Dennehy, PhD[8,9]; Nicolae Sapoval[12]; Katherine Ensor, PhD[12]; Todd Treangen, PhD[12]; Lauren B. Stadler, PhD[12]; Loren Hopkins, PhD[12,13] (VIEW AUTHOR AFFILIATIONS)

Tracking variant prevalence

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EMERGING INFECTIOUS DISEASES®

Research Letter

Correlation between Clinical and Wastewater SARS-CoV-2 Genomic Surveillance, Oregon, USA

Devrim Kaya, Rebecca Falender, Tyler Radniecki, Matthew Geniza, Paul Cieslak, Christine Kelly, Noah Lininger, and Melissa Sutton

Author affiliations: Oregon State University, Corvallis, Oregon, USA (D. Kaya, T. Radniecki, M. Geniza, C. Kelly); Oregon Health Authority Portland, Oregon, USA (R. Falender, P. Cieslak, N. Lininger, M. Sutton)

Association with high community incidence rates

July 26, 2023

Use of Wastewater Metrics to Track COVID-19 in the US

Meri R. J. Varkila, MD[1]; Maria E. Montez-Rath, PhD[2]; Joshua A. Salomon, PhD[3]; Xue Yu, MS[2]; Geoffrey A. Block, MD[4]; Douglas K. Owens, MD[3]; Glenn M. Chertow, MD[2,5]; Julie Parsonnet, MD[1,5]; Shuchi Anand, MD[2]

Author Affiliations | Article Information

JAMA Netw Open. 2023;6(7):e2325591. doi:10.1001/jamanetworkopen.2023.25591

Early warning for community-level surges

Separating signal from noise in wastewater data: An algorithm to identify community-level COVID-19 surges in real time

Aparna Keshaviah, Ian Huff, Xindi C. Hu, Virginia Guidry, Ariel Christensen, Steven Berkowitz, Stacie Reckling, Rachel T. Noble, Thomas Clerkin, Denene Blackwood, Sandra L. McLellan, Adélaïde Roguet, and Isabel Musse -9 Authors Info & Affiliations

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July 25, 2023 | 120 (31) e2216021120 | https://doi.org/10.1073/pnas.2216021120

Estimating true infection burden

Lancet Planet Health. 2021 Dec;5(12):e874-e881. doi: 10.1016/S2542-5196(21)00230-8.

COVID-19 wastewater epidemiology: a model to estimate infected populations

Christopher S McMahan[1], Stella Self[2], Lior Rennert[3], Corey Kalbaugh[3], David Kriebel[4], Duane Graves[5], Cameron Colby[6], Jessica A Deaver[7], Sudeep C Popat[7], Tanju Karanfil[7], David L Freedman[8]

https://doi.org/10.17226/26767

Covid-19 wastewater surveillance is promising tool, but critical challenges remain

CNN health

By Deidre McPhillips, CNN

Updated 8:49 AM EDT, Wed May 18, 2022

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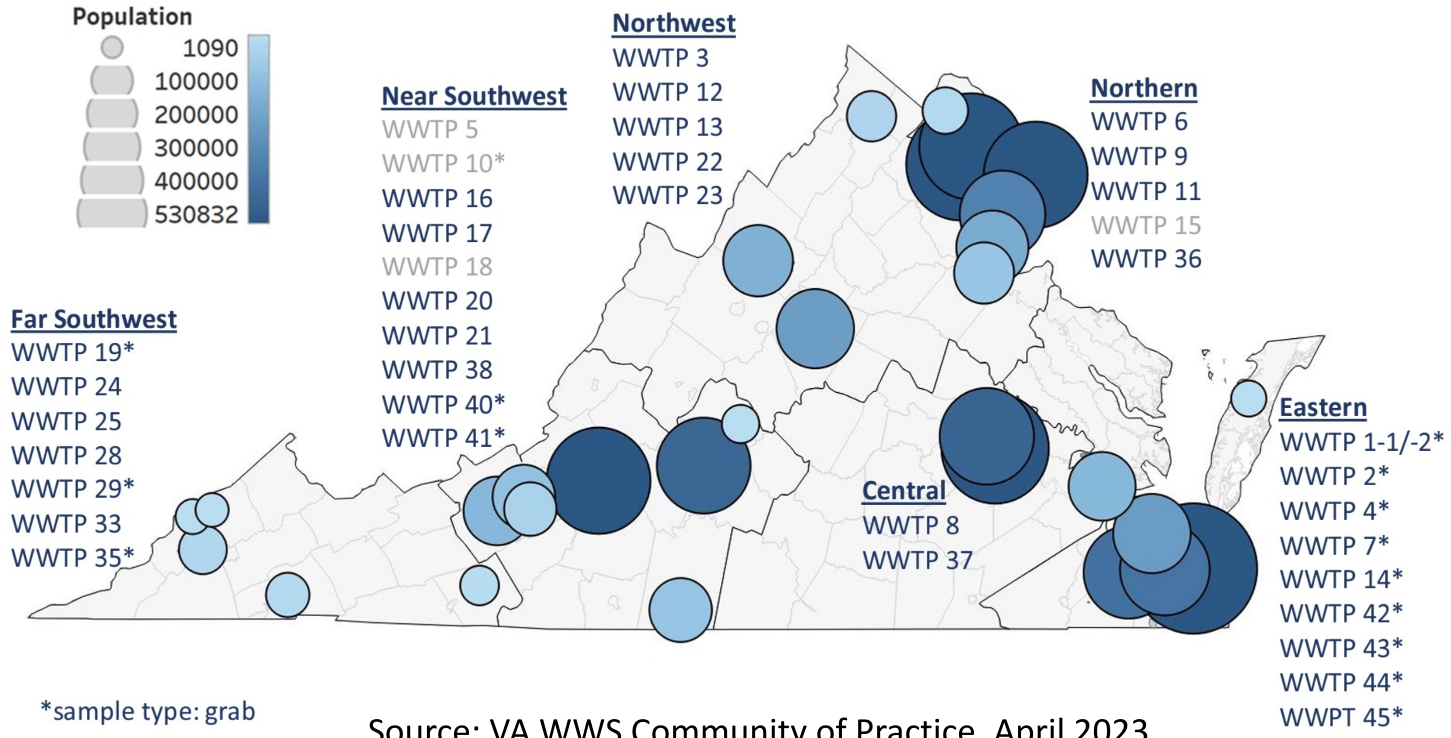
Key Questions

- How much ***predictive power*** does the wastewater surveillance time series (WWSTS) have for forecasting COVID-19 incidence?
- What are some of the ***challenges*** in working with WWSTS?
- What are some potential ***approaches*** to increase the utility of WWSTS?

Wastewater surveillance in Virginia

Sentinel Monitoring Facilities



*sample type: grab

Source: VA WWS Community of Practice, April 2023

Total 36 wastewater treatment plants (as of April 2023)

- 13 sampling twice weekly
- 23 sampling once weekly

Variant sequencing

- 20-23 (rotating) sites weekly

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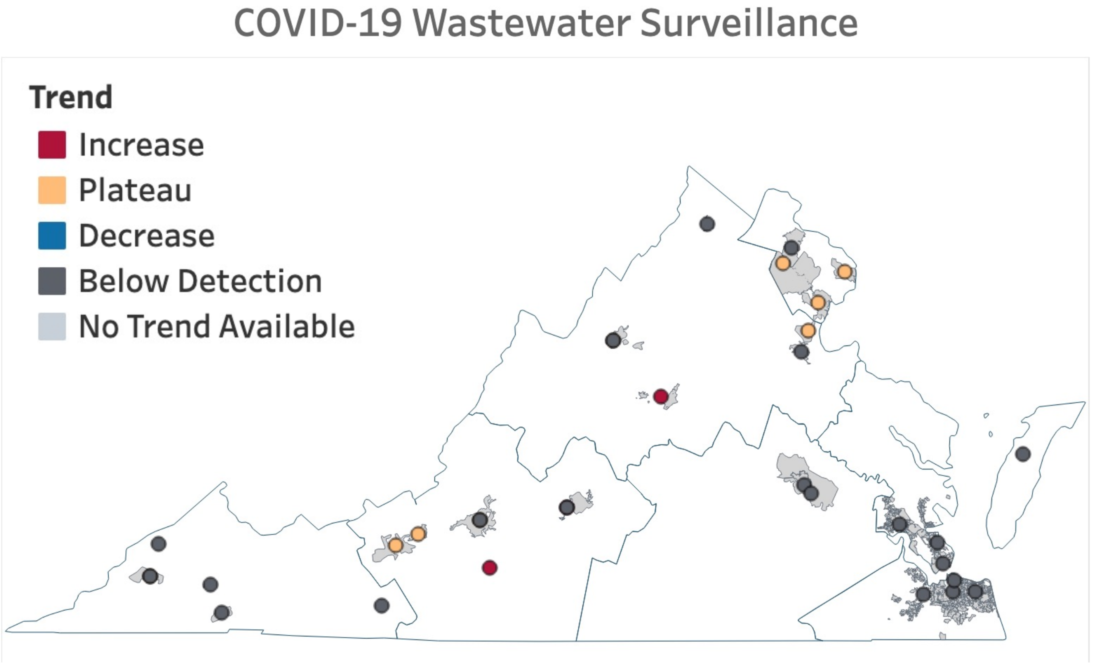
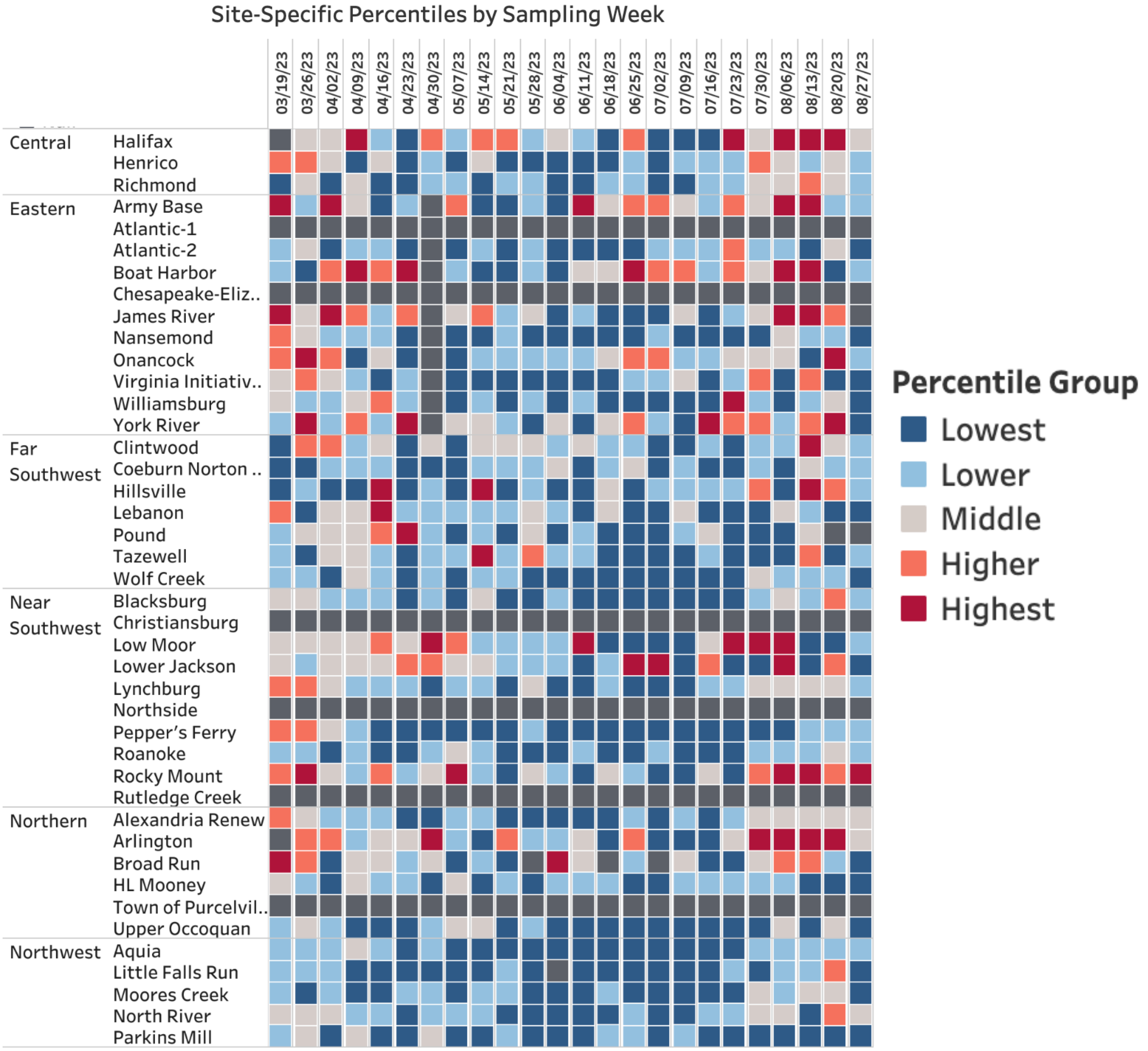
Public Communication



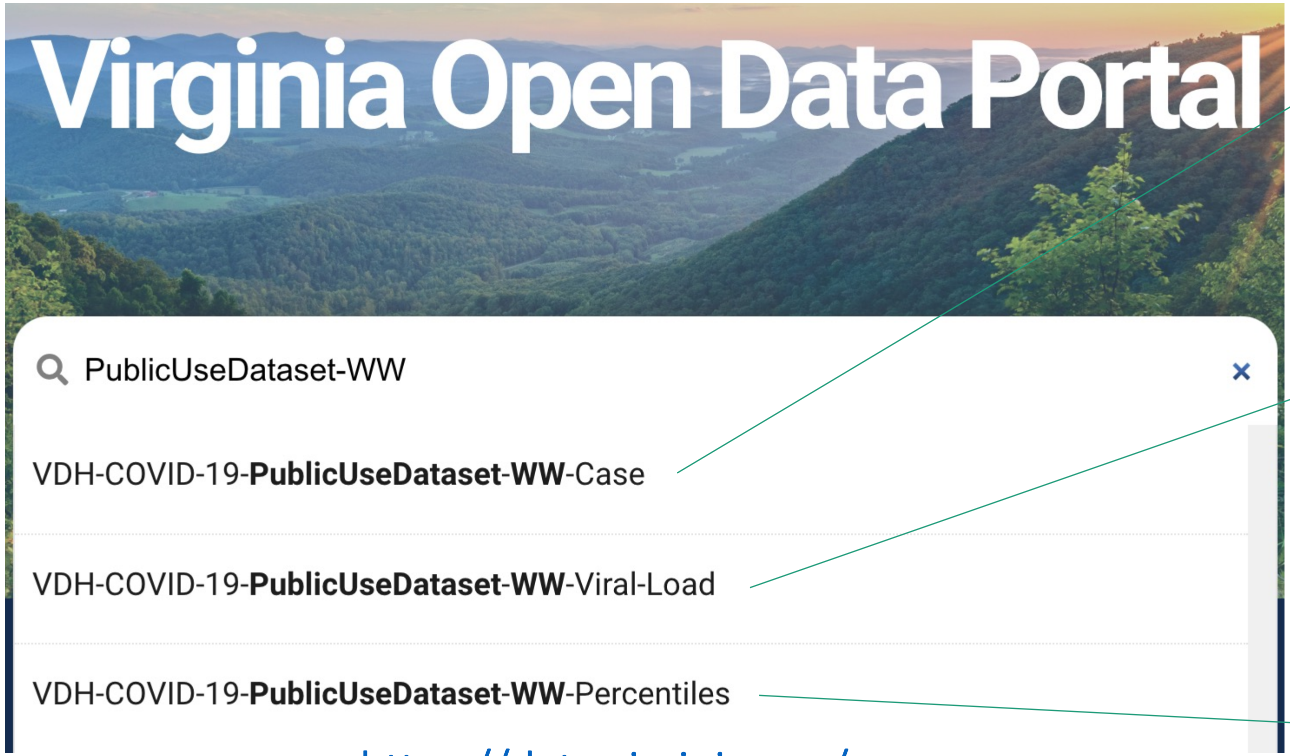
Trend Indicator

https://www.vdh.virginia.gov/coronavirus/see-the-numbers/covid-19-data-insights/sars-cov-2-in-wastewater/



Percentile Indicator

Public datasets



https://data.virginia.gov/

Cumulative cases by **sewershed (WWTP service area)** by event date

Weekly viral concentration by sewershed by sample collection week

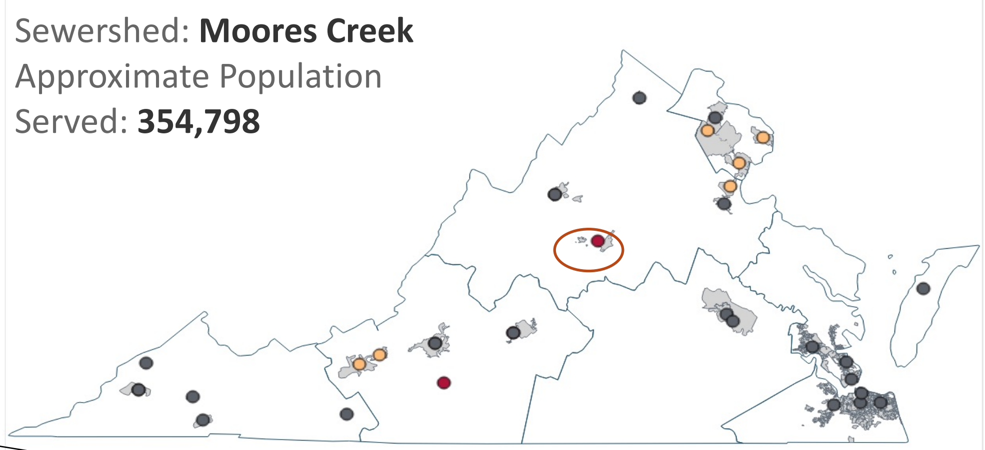
Weekly percentile and percentile groups by sewershed by collection week

Additional data fields and interpretation

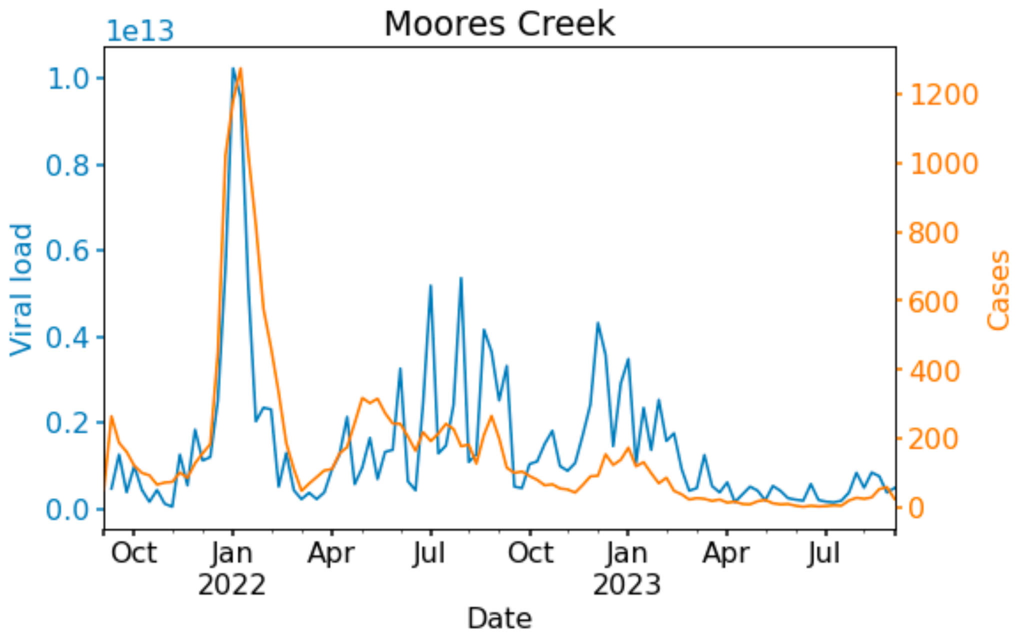
- Sampling methods:
  - Sample type: grab vs 24-hour composite
  - Sample matrix: raw wastewater vs post-grit removal
- Viral Measurements:
  - Limit of Detection for ddPCR analysis
  - Volumetric daily flow rate (million gallons/day)
  - Number of copies of PCR target per volume (copies/L)
  - Number of copies of PCR target per day (copies/day)

Viral Load (VL)

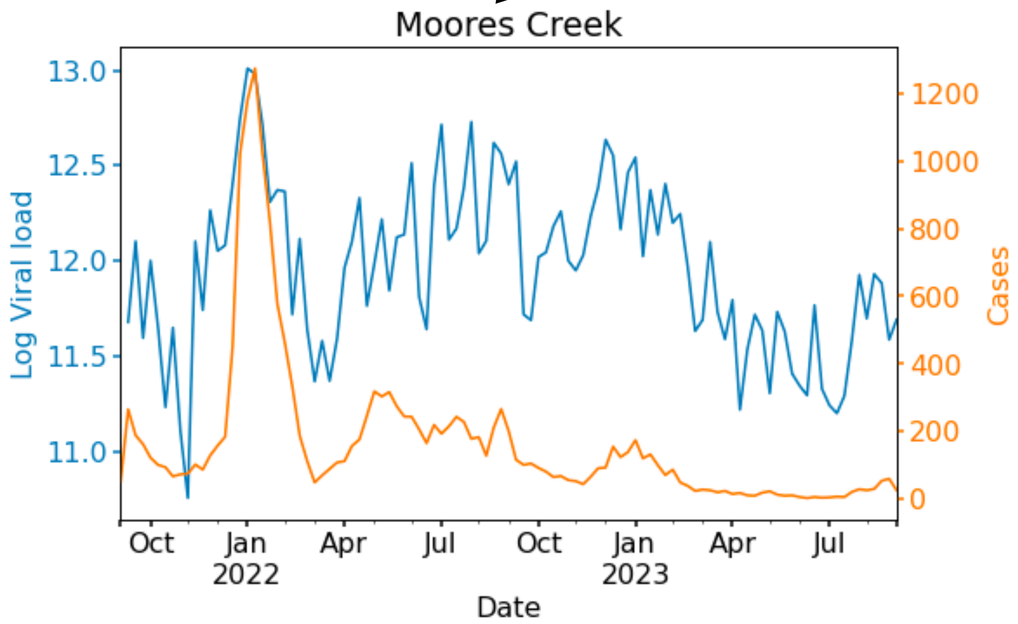
Visual comparison



Sewershed capturing Charlottesville-Albemarle counties



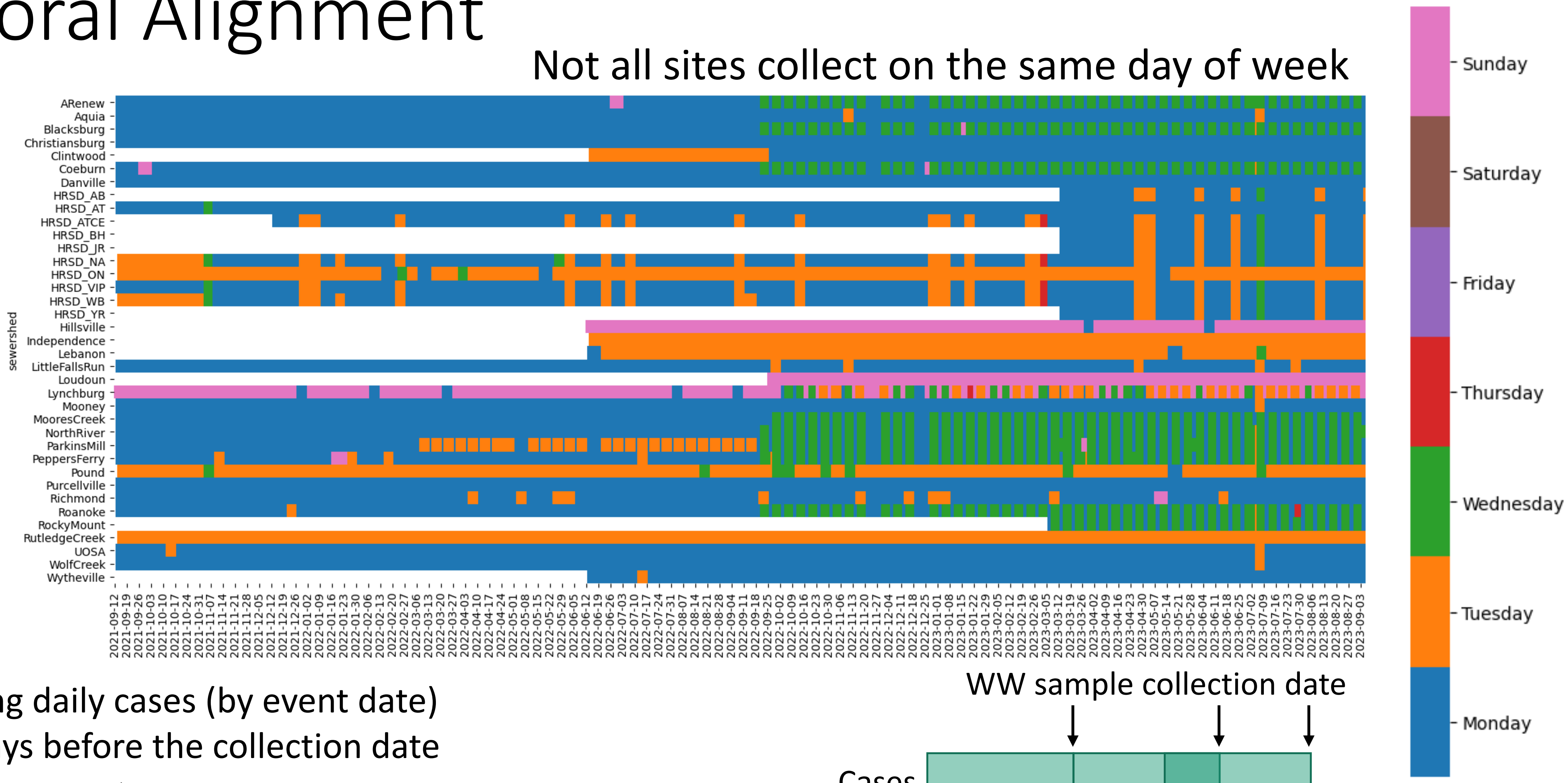
Viral load (copies/day)



After log transformation

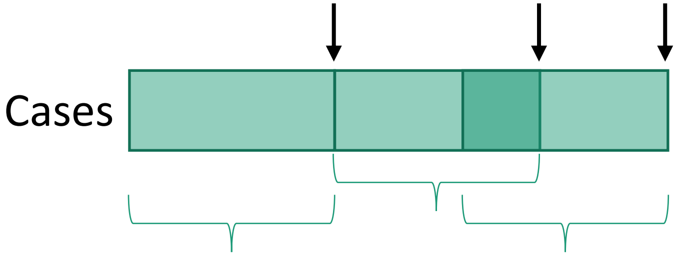
Temporal Alignment

Not all sites collect on the same day of week



Aggregating daily cases (by event date) in the 7 days before the collection date

$$c_w(t) = \sum_{i=0}^{p-1} c(t-i)$$



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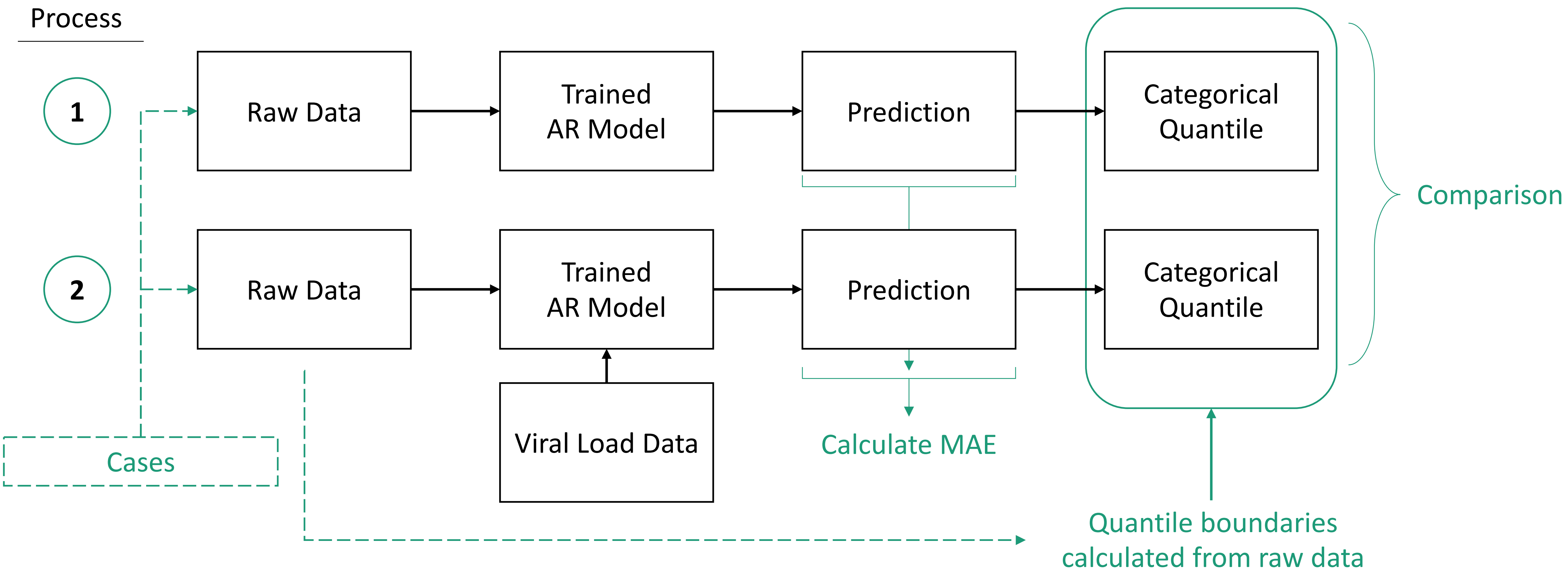
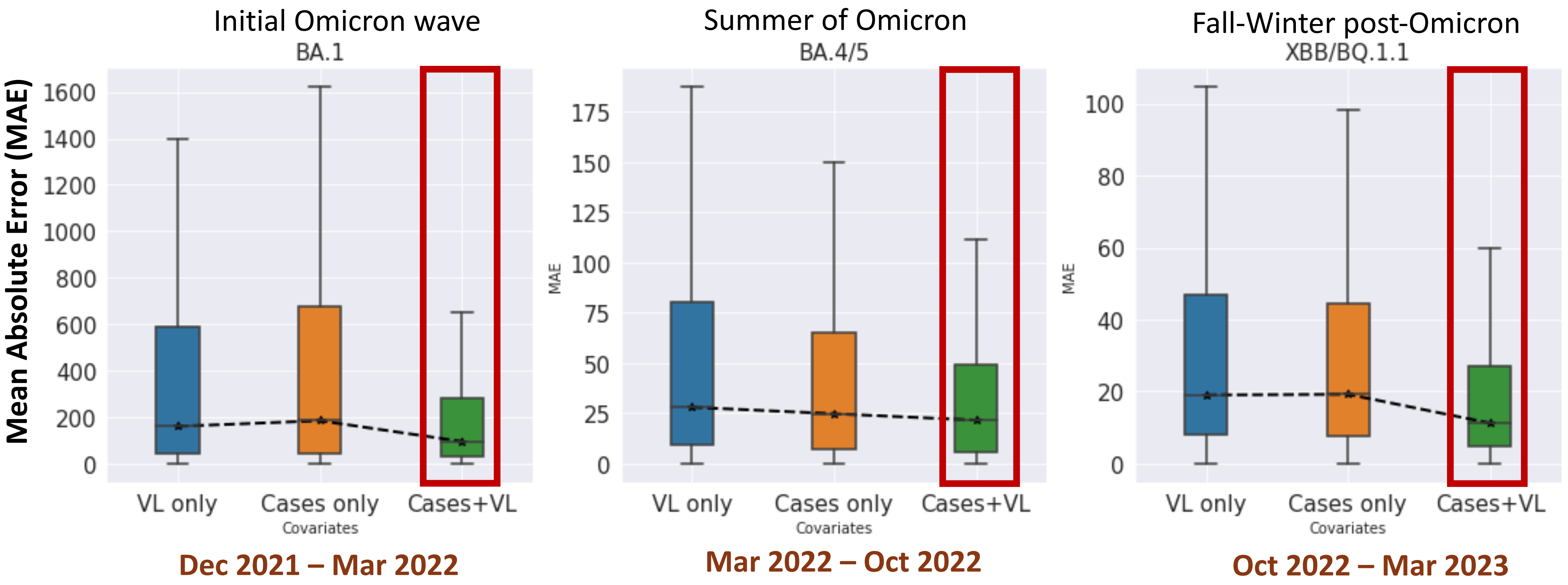
Analysis Framework



Cases Prediction Performance (Across Waves)



- Cases + VL model has lower median and IQR for MAE
- Performance improvement higher during winter waves

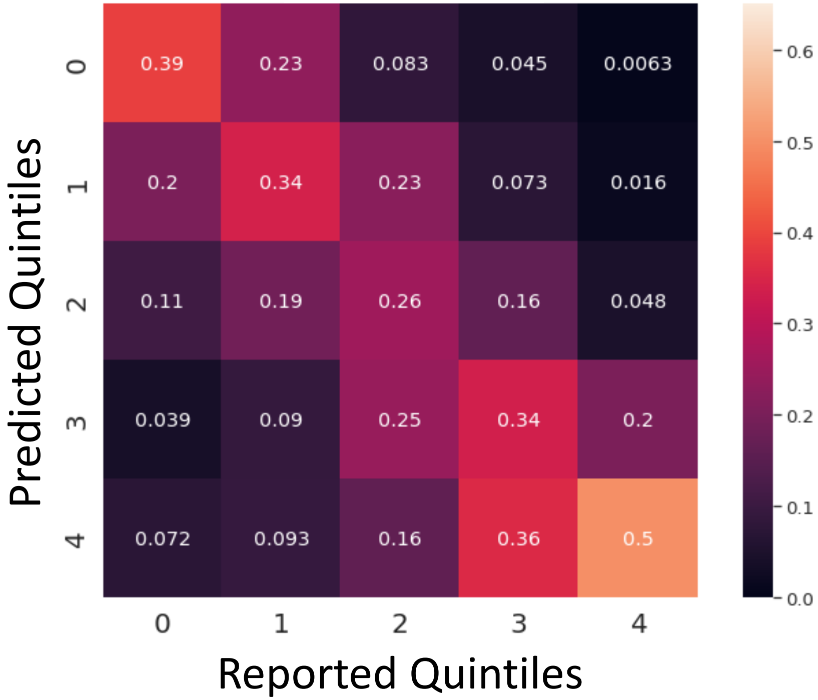
VL only: Model trained on Viral Loads only
Cases only: Model trained on Cases only
Cases+VL: Model trained on both Viral Load and Cases

Categorical comparison of predictions

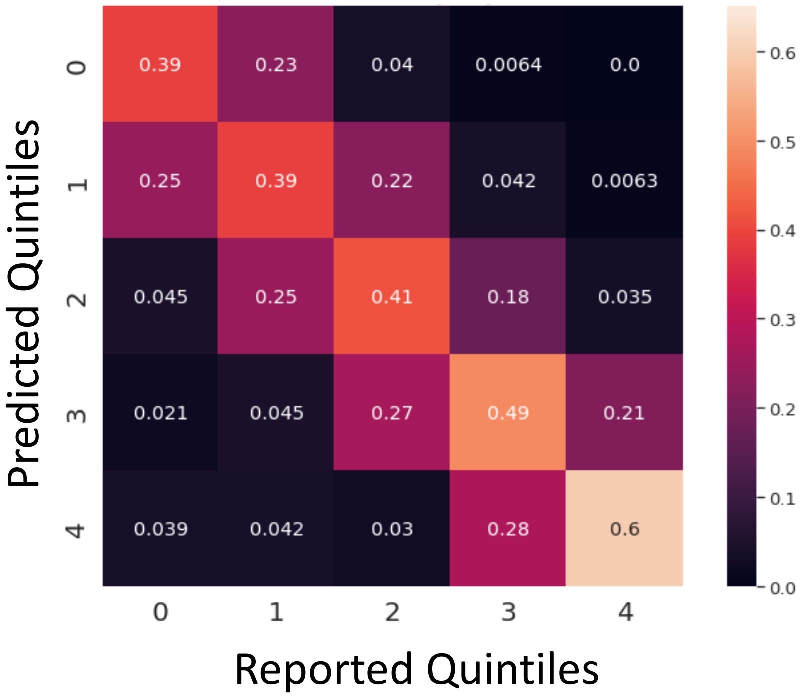
- Convert case ground truth into quintiles
- Map each prediction into one of these bins (from ground truth)
- Better recall for highest quintiles; Cases + VL performs better

VL only

Cases only



Cases + VL



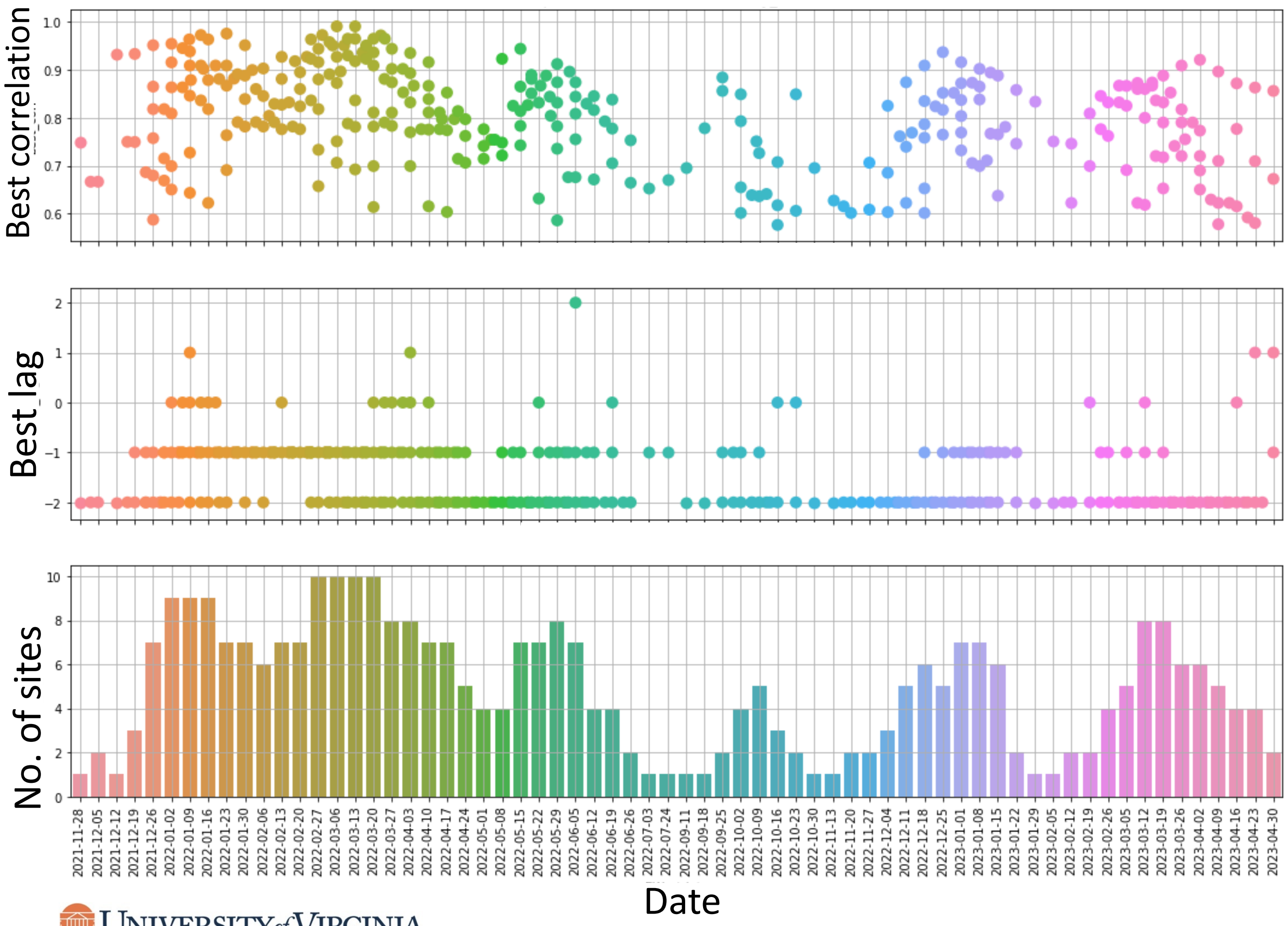
Correlation analyses at Sewershed level

- A correlation-based lead-lag analysis with a rolling window of 12 weeks

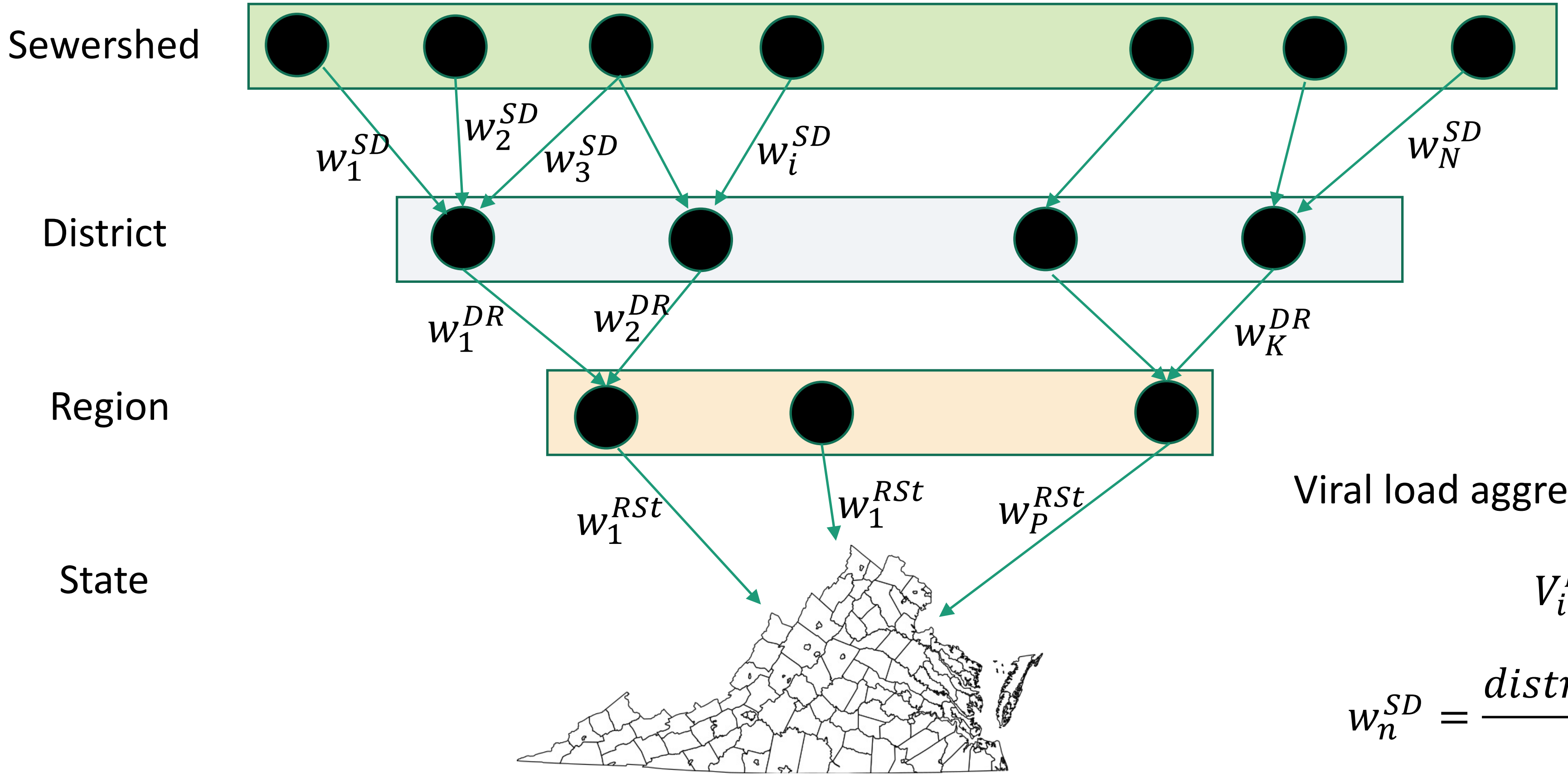
Corr(VL(t+lag), cases(t))

- Variability in lag across time and sites, but mostly VL leads cases by 1-2 weeks

- The number of sites with statistically significant correlation increases during times of surge



Need for Multi-Signal Approach



Feature Resolution

Viral loads, Cases

Hospitalizations, CLI

Viral load aggregation from Sewersheds to Districts

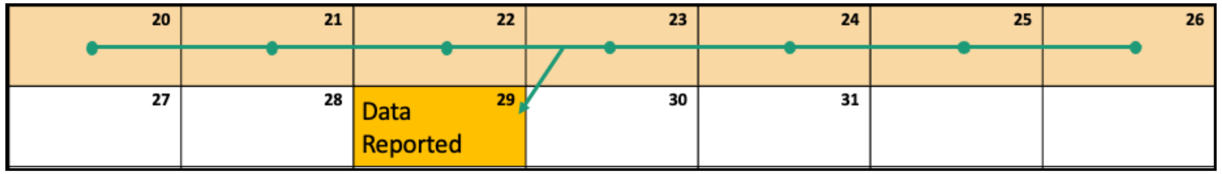
$$V_i^D(t) = \sum_{n=1}^{N} w_n^{SD} V_n^S(t)$$

$$w_n^{SD} = \frac{district\ pop.served\ by\ sewershed}{total\ district\ pop.served}$$

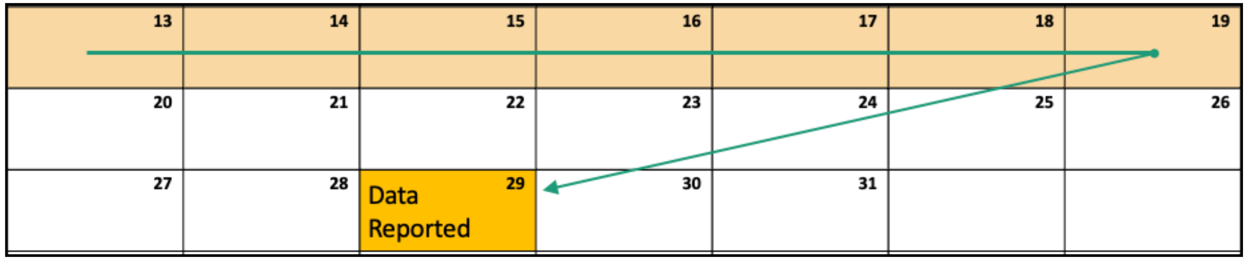
Aligning Reporting Cadences

"Latest" data available as of August 29th, 2023

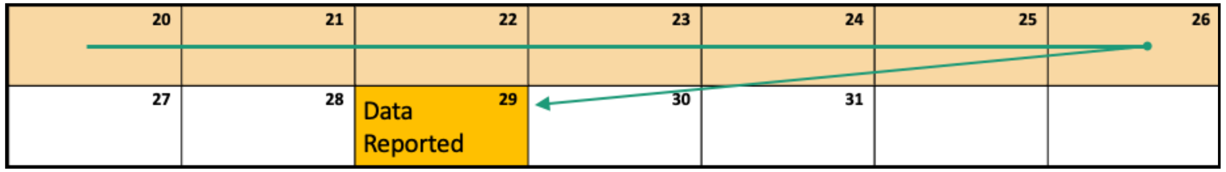
Cases (**Daily** data for the Epi week of **Aug 20th**)



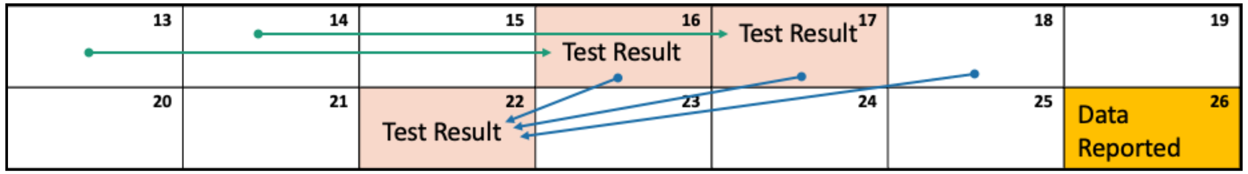
Hospitalizations (**Weekly** data for the Epi week of **Aug 13th**)



CLI (**Weekly** data for the Epi week of **Aug 20th**)



Wastewater (**Staggered** data for the Epi week of **Aug 13th**)



Key Takeaways

- **Initial findings:**
  - Including viral load data in the model improves case forecasting accuracy
    - Performance improvement decays for subsequent Omicron waves
  - High correlation and categorical alignment observed during peak activity

- **Challenges:**
  - Need to account for variable sampling and signal noise
  - Need to align with other signals across spatial resolutions
  - Processing & reporting lags could impact real-time predictive power

- **Ongoing work:**
  - Categorical forecasting of multiple signals with spatiotemporal alignment