Western Interstate Energy Board

2024 Shultz Energy Fellowship
Transmission Use and Congestion Analysis in the Western States

Owen Jung & Yueer Cai

My Background

- Yueer Cai (She/her)
- M.S. in Sustainable Design and Construction, Stanford University
- B.S. in Civil Engineering, University of Illinois at Urbana-Champaign
- Favorite hobbies: food lover, travel enthusiast
- First generation college student

My Background

- Owen Jung (He/him)
- B.S. in Data Science and B.A. in English, Stanford University
- Hometown: Oakland, CA
- Favorite hobbies: music, basketball, beach volleyball

Outline

- Project Overview
- Background: Locational Marginal Prices (LMPs) and Congestion
- Data Sources and Methods of Analysis
- Seasonal Variation in Congestion
- Zooming In: Temperature and Congestion
- Clustering Analysis
- Takeaways and Recommendations

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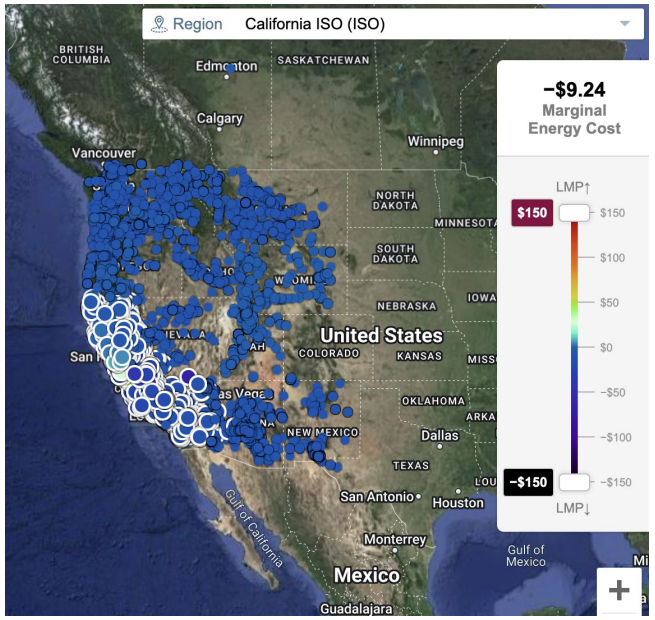
Project Overview

- Analyze CAISO WEIM LMPs with statistical models to better understand congestion and energy transmission in the Western Energy Imbalance Market (WEIM)
- Connect with external advisors & with subject matter experts in modeling the electric system
- Demonstrate how states should interpret these “price signals” as key indicators of transmission needs as markets in the West develop



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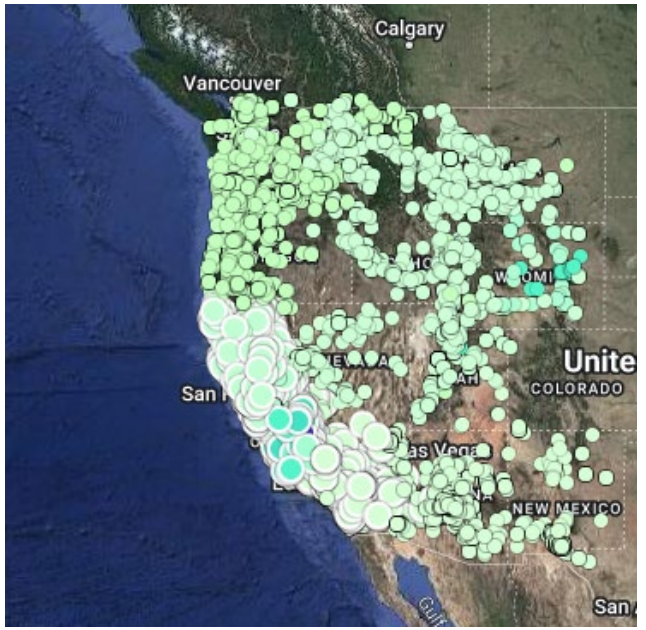
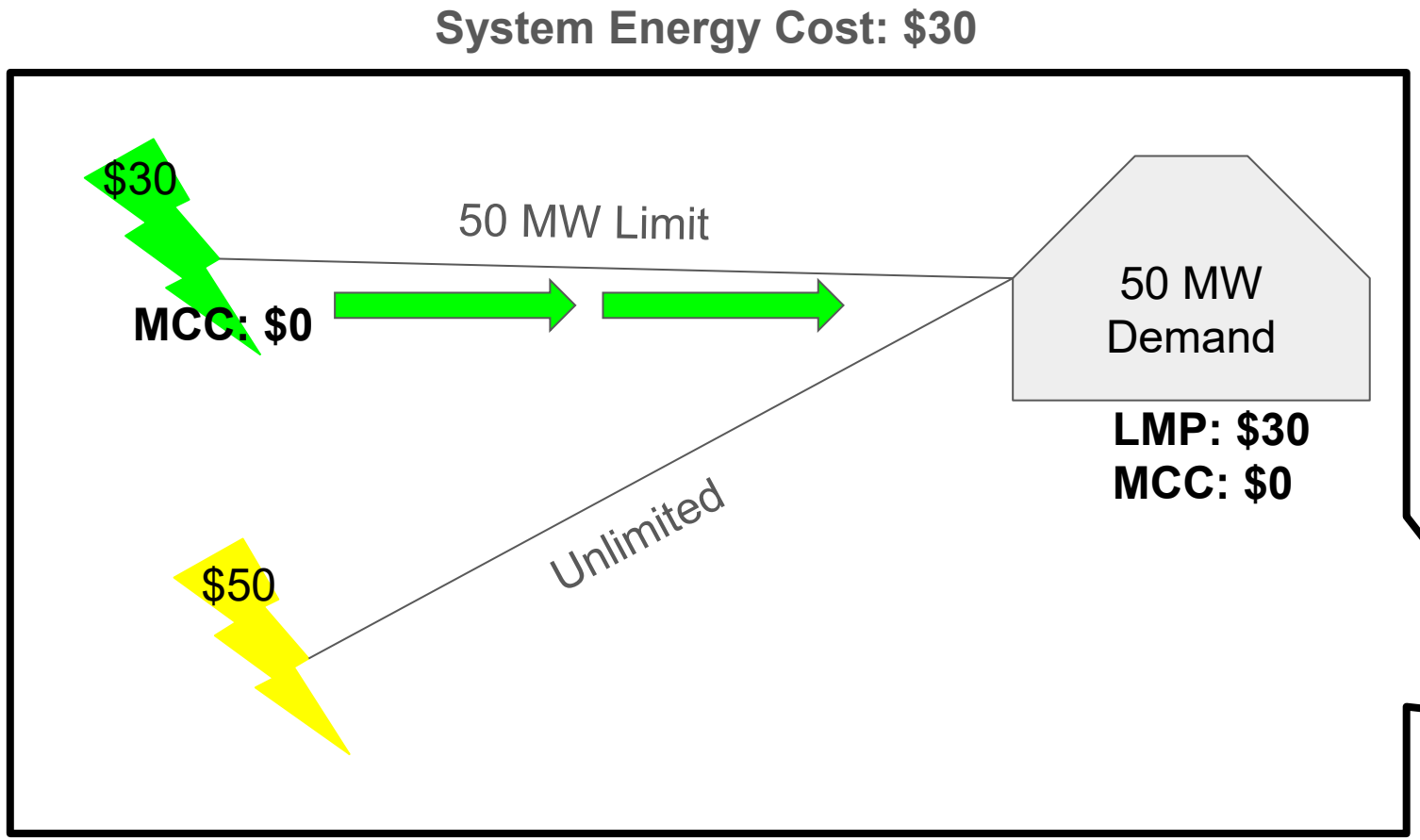
Locational Marginal Prices and Congestion

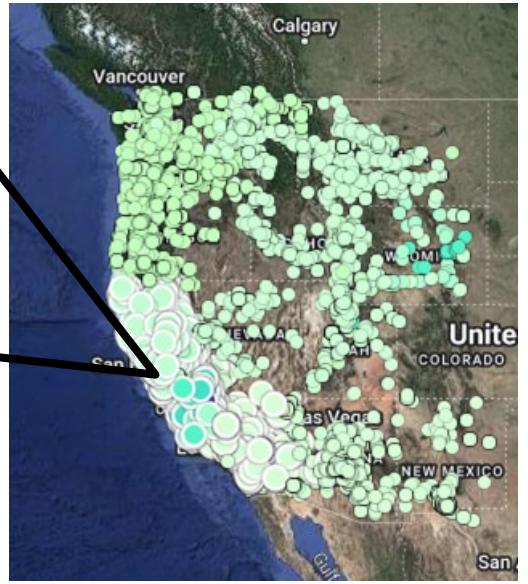
LMP = System Energy Price + Transmission Congestion Cost + Cost of Marginal Losses

- System Energy Price set at a “reference bus,” meant to represent price across the grid’s entirety
- Congestion and marginal losses make up the difference between reference price (system energy price) and the actual price at a node
- Congestion makes up the majority of these differences, losses are marginal

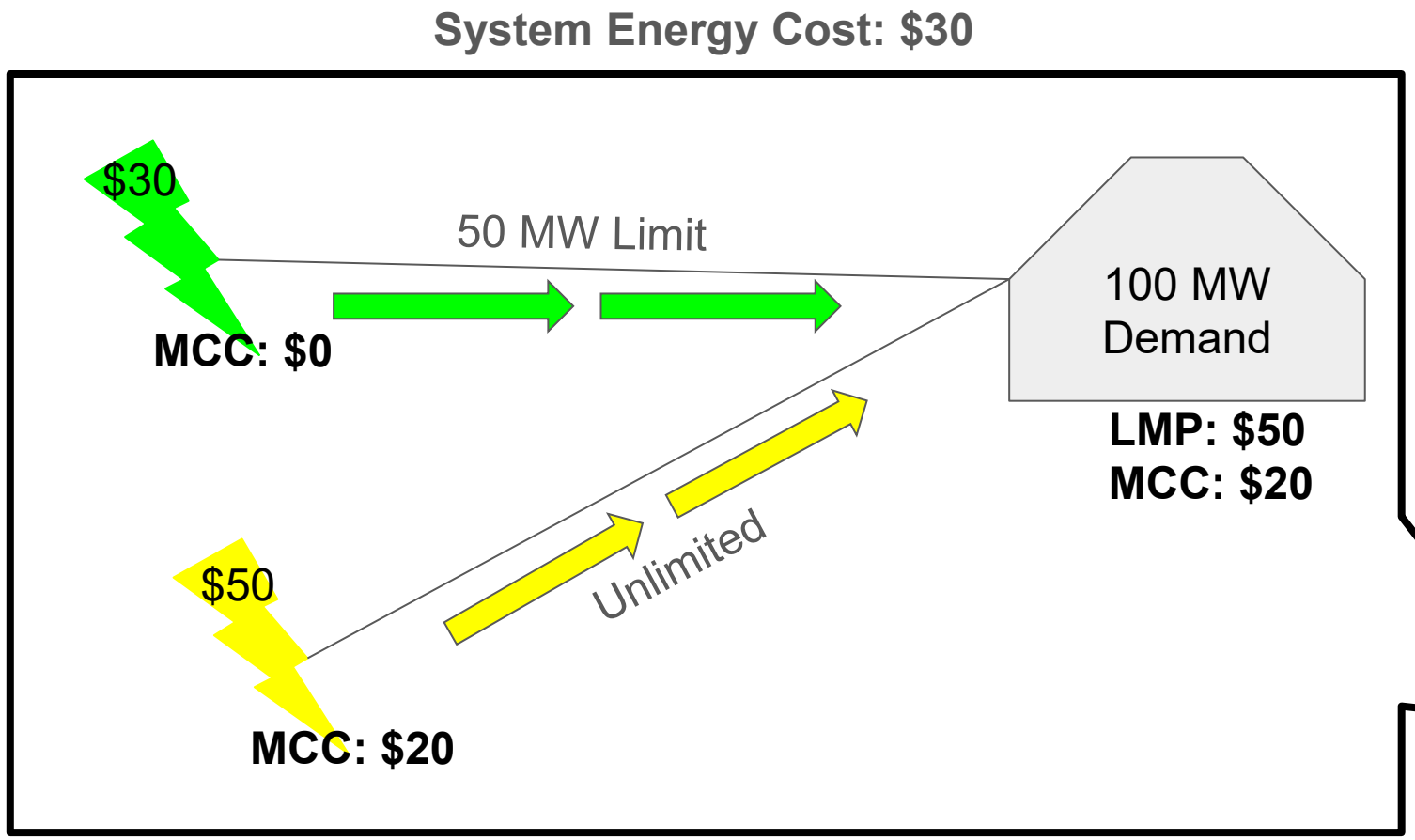


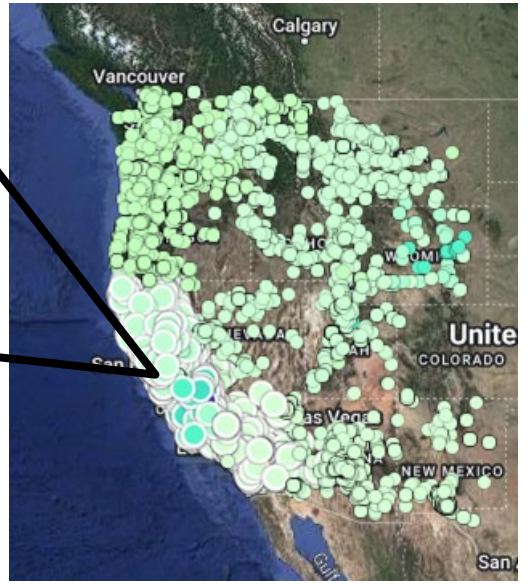
A Snapshot of LMPs - No Congestion





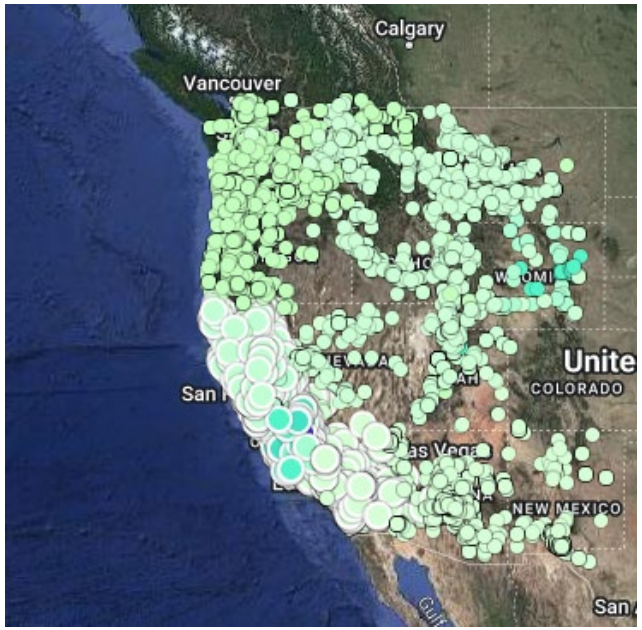
A Snapshot of LMPs - With Congestion





Congestion Cost Recap:

	Load	Generating
Positive MCC	Paying higher costs due to congestion	Selling expensive energy because of congestion
Negative MCC	Paying lower costs due to congestion	Generating cheap energy, not selling it because of congestion



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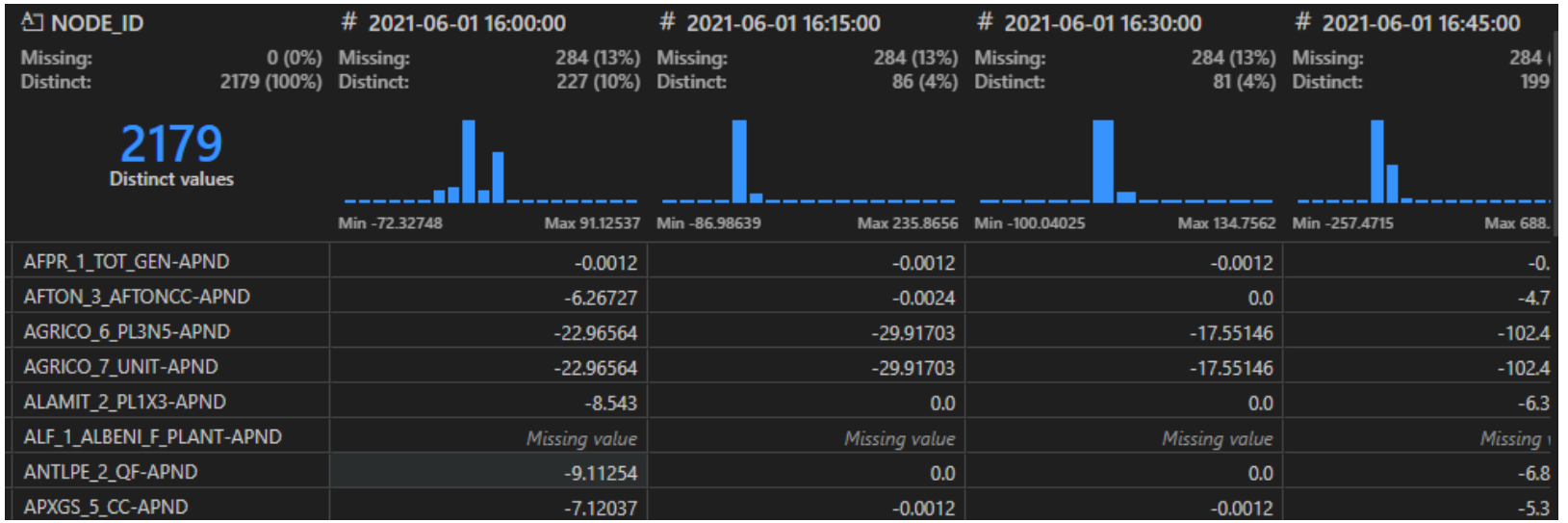
Our Data



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Missing: 0 (0%) Distinct: 2179 (100%)	Missing: 284 (13%) Distinct: 227 (10%)	Missing: 284 (13%) Distinct: 86 (4%)	Missing: 284 (13%) Distinct: 81 (4%)	Missing: 284 Distinct: 199
2179 Distinct values	Min -72.32748 Max 91.12537	Min -86.98639 Max 235.8656	Min -100.04025 Max 134.7562	Min -257.4715 Max 688.
AFPR_1_TOT_GEN-APND	-0.0012	-0.0012	-0.0012	-0.
AFTON_3_AFTONCC-APND	-6.26727	-0.0024	0.0	-4.7
AGRICO_6_PL3N5-APND	-22.96564	-29.91703	-17.55146	-102.4
AGRICO_7_UNIT-APND	-22.96564	-29.91703	-17.55146	-102.4
ALAMIT_2_PL1X3-APND	-8.543	0.0	0.0	-6.3
ALF_1_ALBENI_F_PLANT-APND	*Missing value*	*Missing value*	*Missing value*	*Missing*
ANTLPE_2_QF-APND	-9.11254	0.0	0.0	-6.8
APXGS_5_CC-APND	-7.12037	-0.0012	-0.0012	-5.3

- From CAISO's OASIS, reflects the fifteen-minute market (FMM) for energy, a real-time market coordinated across the entirety of the WEIM
- Time frame: June 2021 - July 2024, peak hours (4-9pm MST)
- 22,700 time entries at roughly 2,200 nodes

- Many calculations were filtered to only include nodes that have been sufficiently active (75% full data) in the past calendar year
- Doesn't take into account CAISO's DAM or the WEIM five-minute market. Also not adapted to bilateral trades

Methods of Analysis:

- Seasonal Analysis
- Mapping
- Examining Correlations Between MCC and Temperature
- Clustering Algorithm

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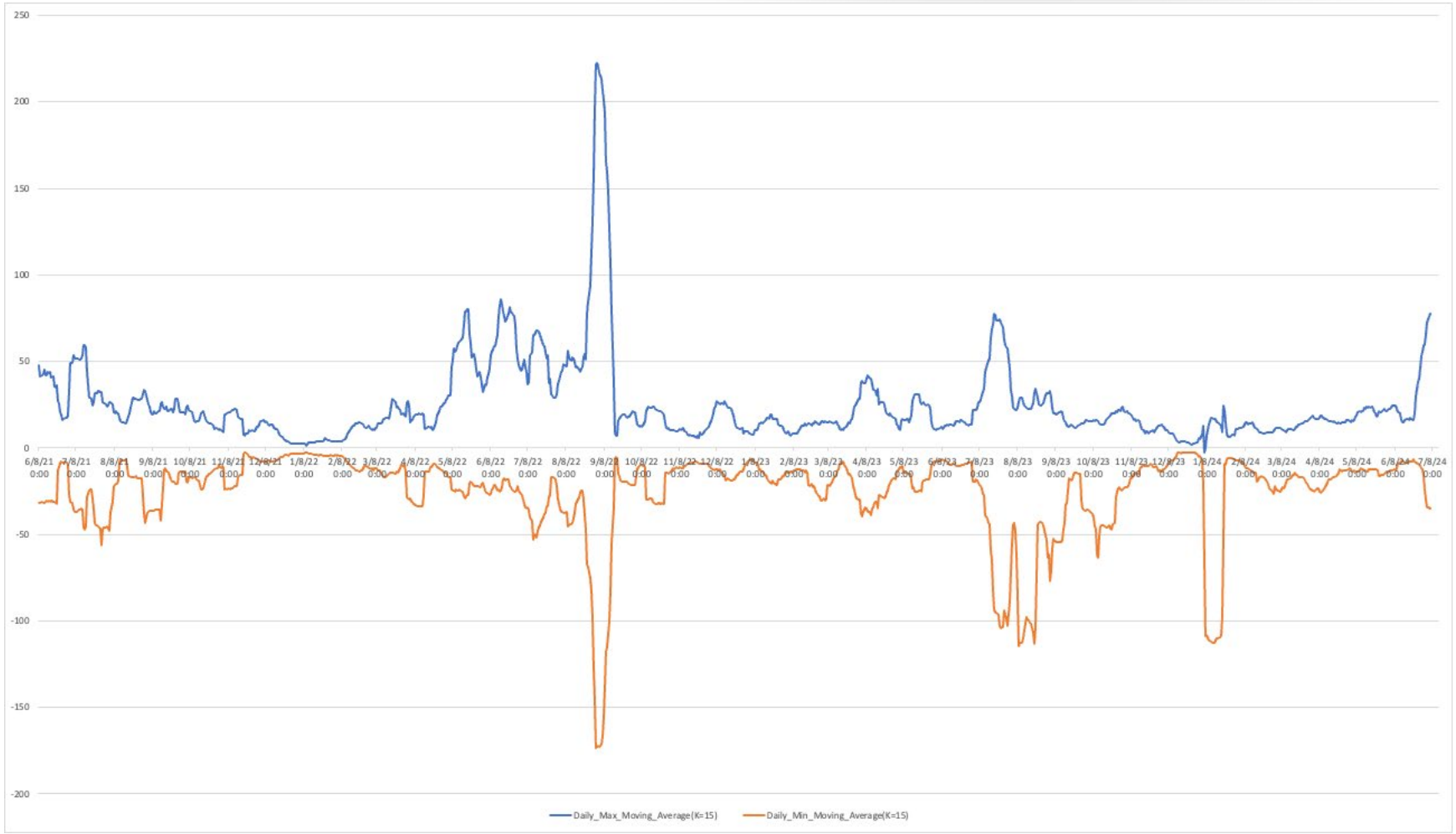
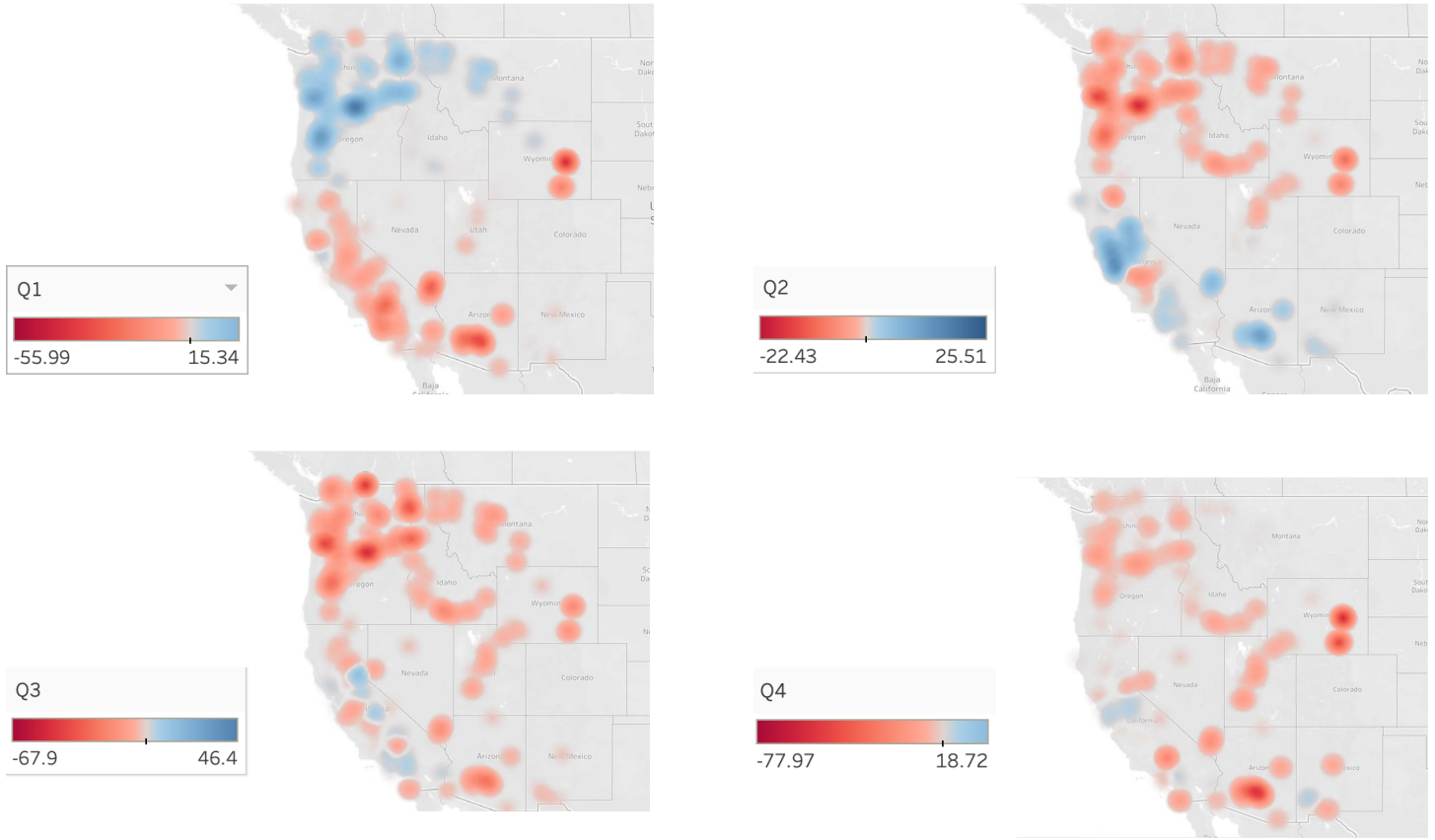
Daily Max and Min Congestion Value (2021-2024)



- Larger positive and negative MCCs co-occur
- Usually the summer season sees peak values
- Winter 2024 saw unusually high congestion

Seasonal Variation in LMP Congestion Components Across the WEIM (4 year)



Average nodal congestion components across the four quarters

Red: negative congestion
Blue: positive congestion

Q2, Q3, Q4 show a similar pattern: positive MCC in California, negative MCC everywhere else.

Unlike during the other seasons, in Q1 the pacific northwest sees positive MCC while the other areas in the EIM see negative MCC.

Q2 has the least congestion and Q4 has the largest congestion

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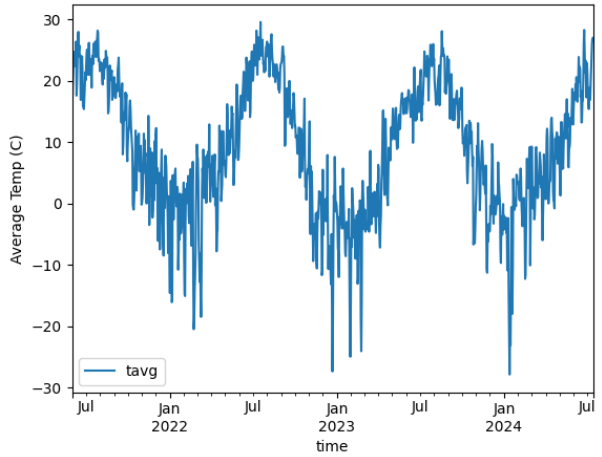
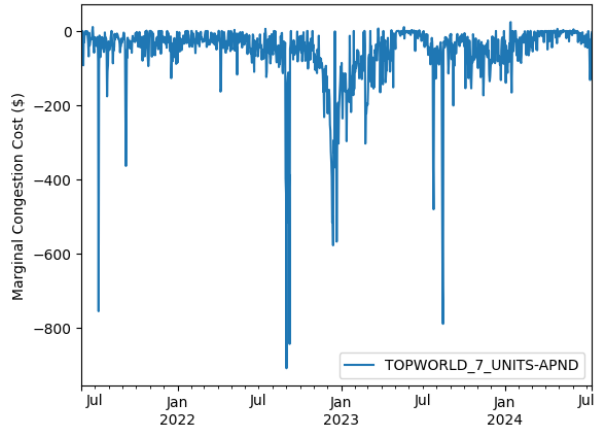
Temperature and Congestion

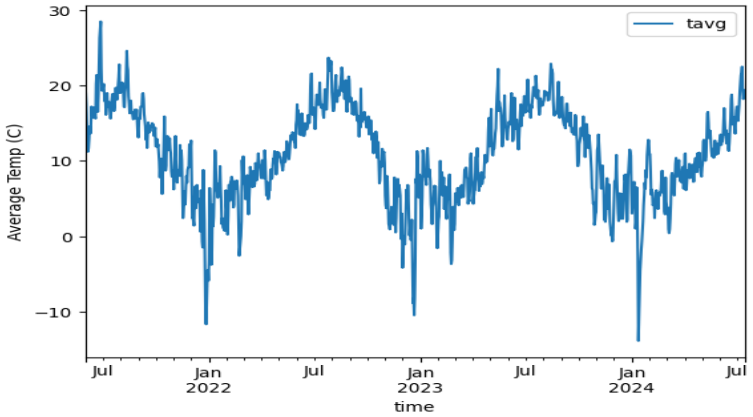
- Example Node: TOPWORLD_7 (near Glenrock and Casper, WY)
- Encompasses one of Wyoming's largest and most efficient wind farms
- Connecting substation for a $500M proposed solar farm
- Bursts of extreme congestion often correspond with periods of extreme local and broader regional temperature
- However, congestion doesn't follow temperature proportionally - the short but intense spikes in congestion will often take place during times of extreme temperature
- August and January are when we see the highest congestion
- In areas of large, renewable generation, it's important to build corresponding transmission

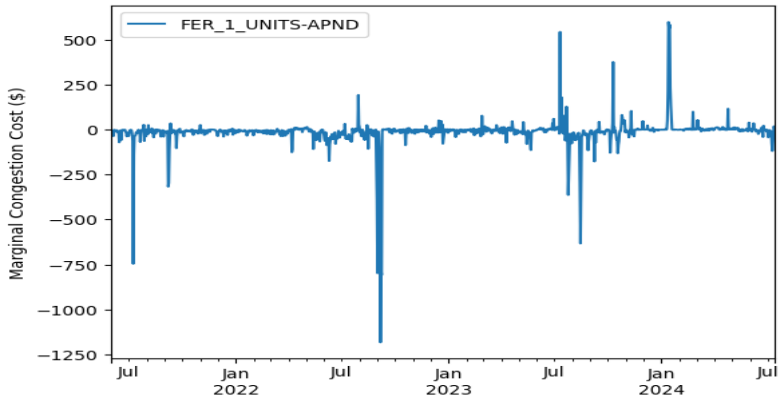




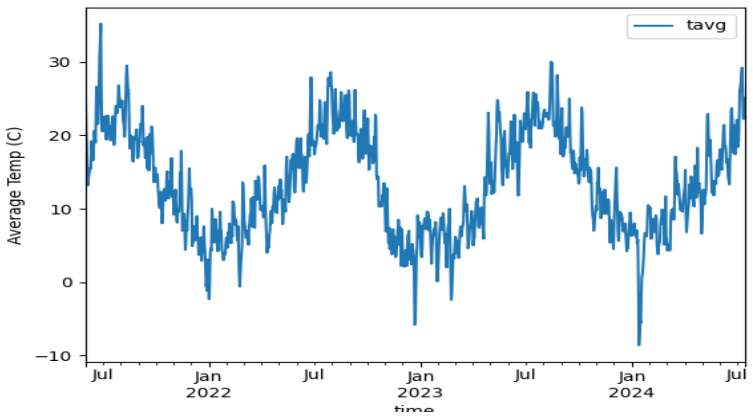
Three More Nodes

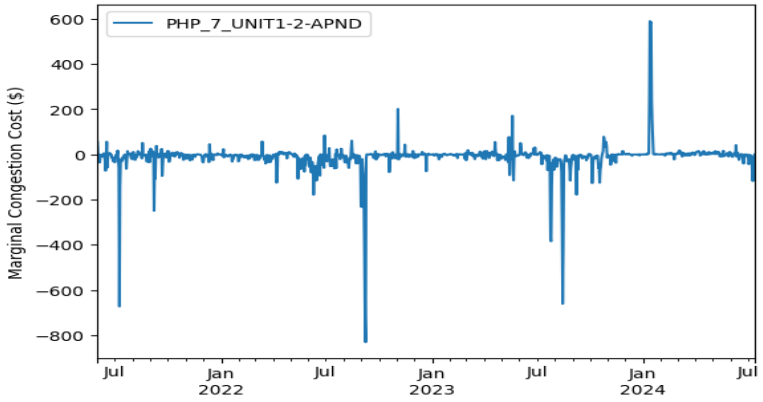
Ferndale, WA



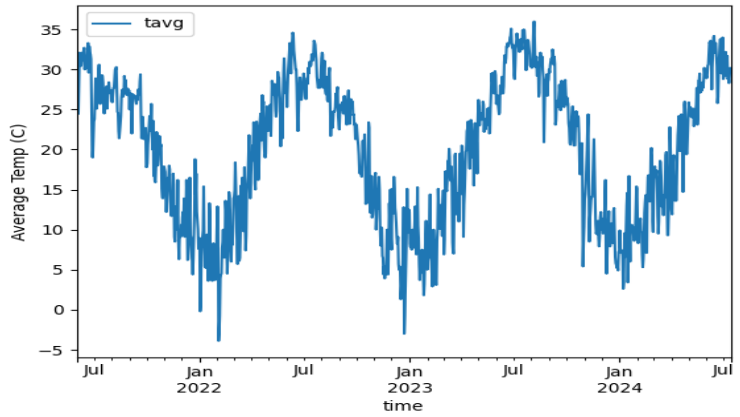


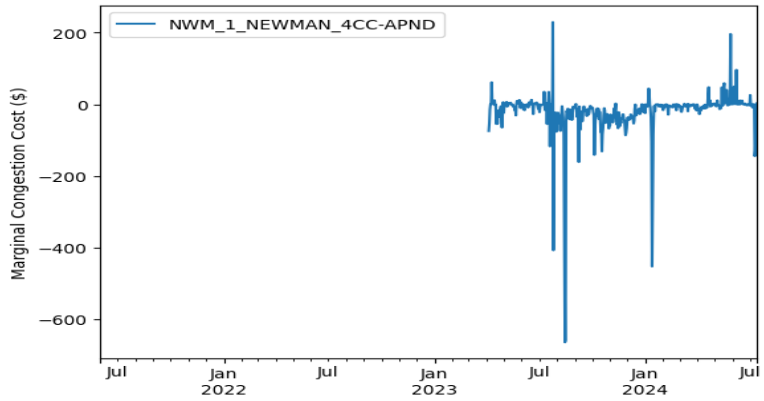
Bull Run, OR





El Paso, TX





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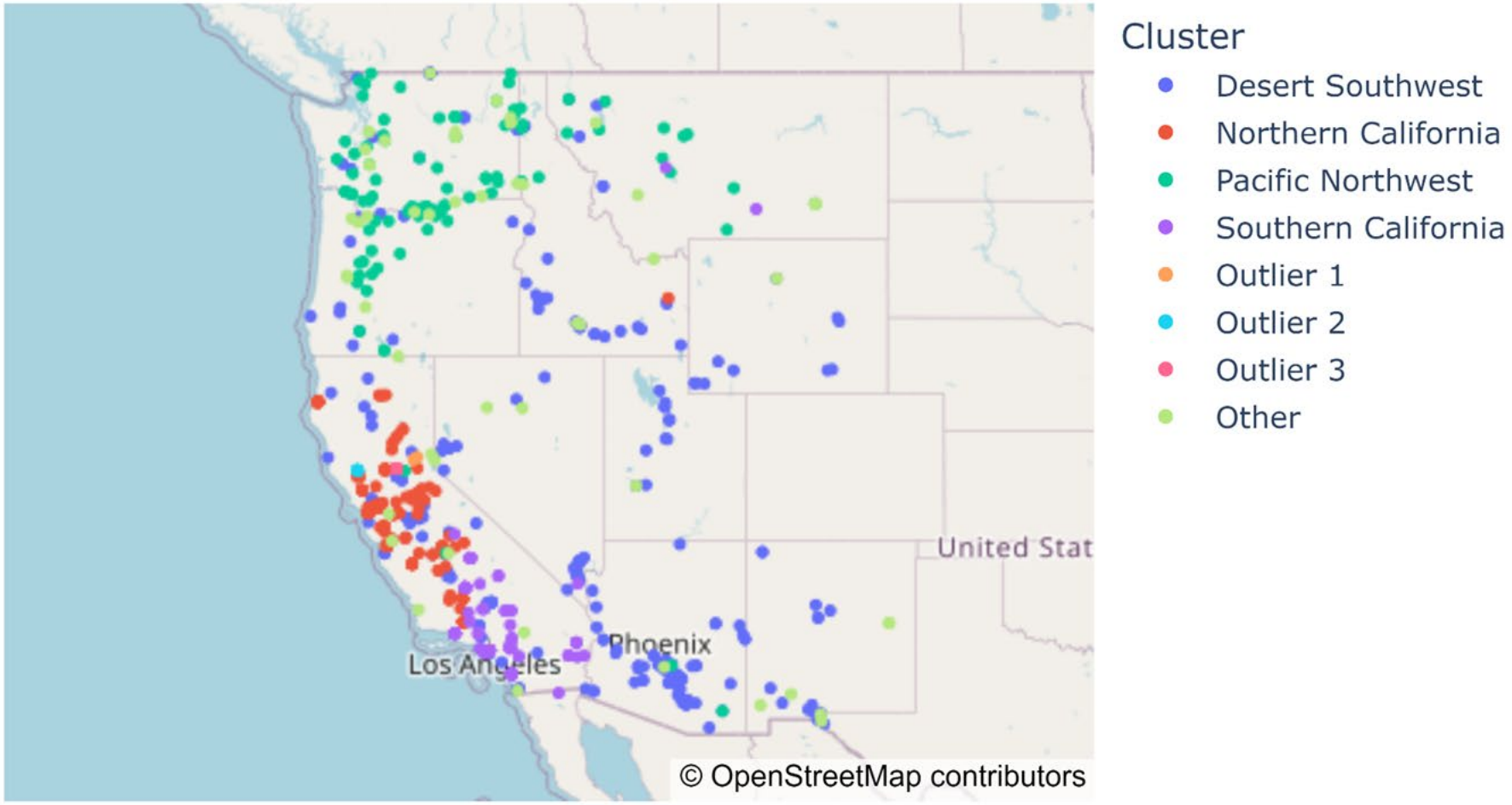
Clustering Method and Analysis:

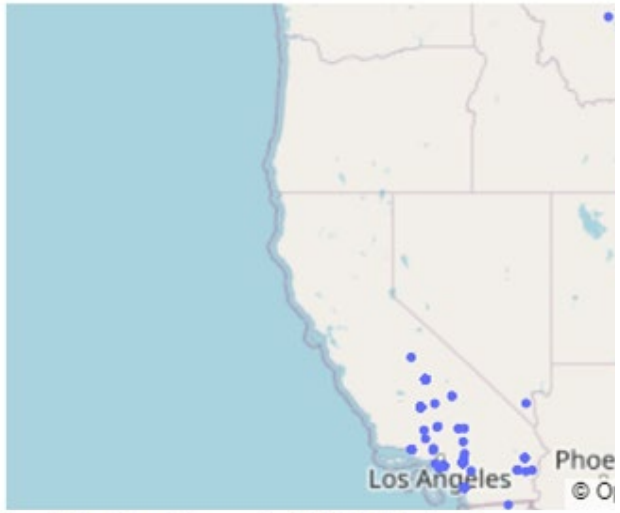
- Measures node similarity
- Grouping nodes by pricing pattern
- Example: Bull Run, OR and Ferndale, WA

Clustering Analysis



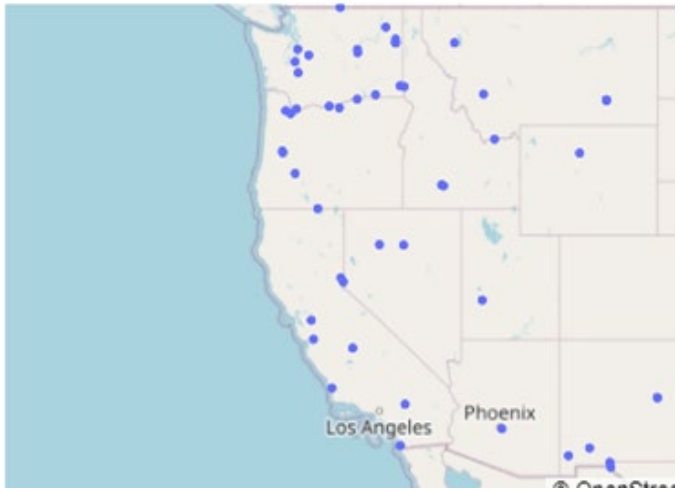
Northern CA (814 Nodes)

Southern California (787 Nodes)

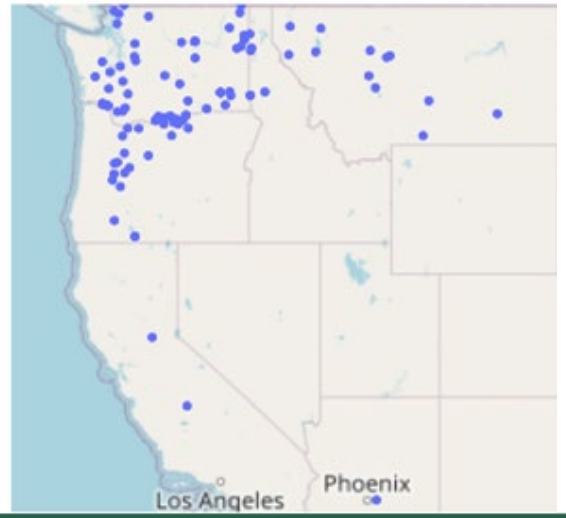


Phoenix Catchall (445 Nodes)

NW Catchall (125 Nodes)



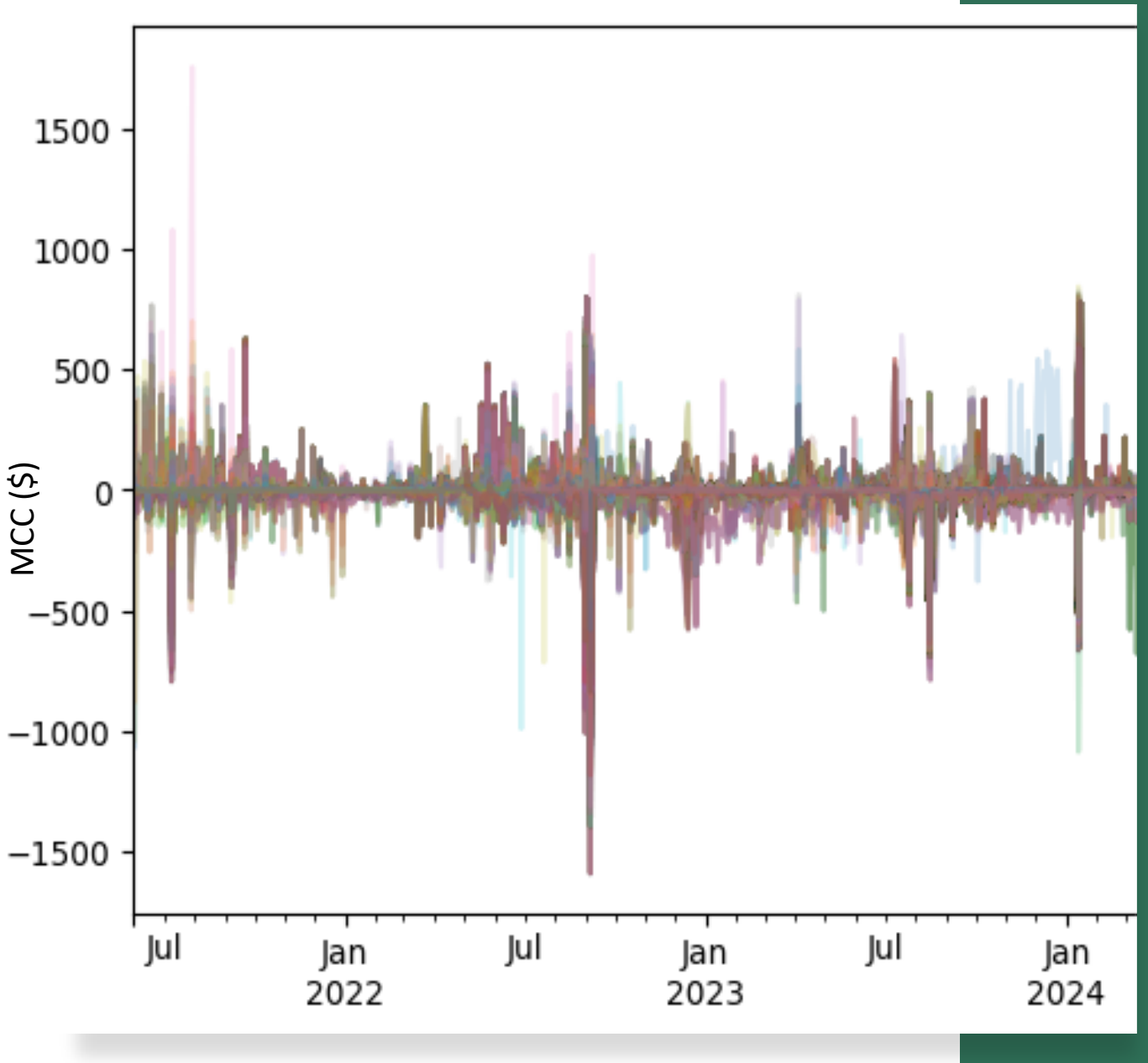
Pacific Northwest (123 Nodes)



Three Outlier Nodes

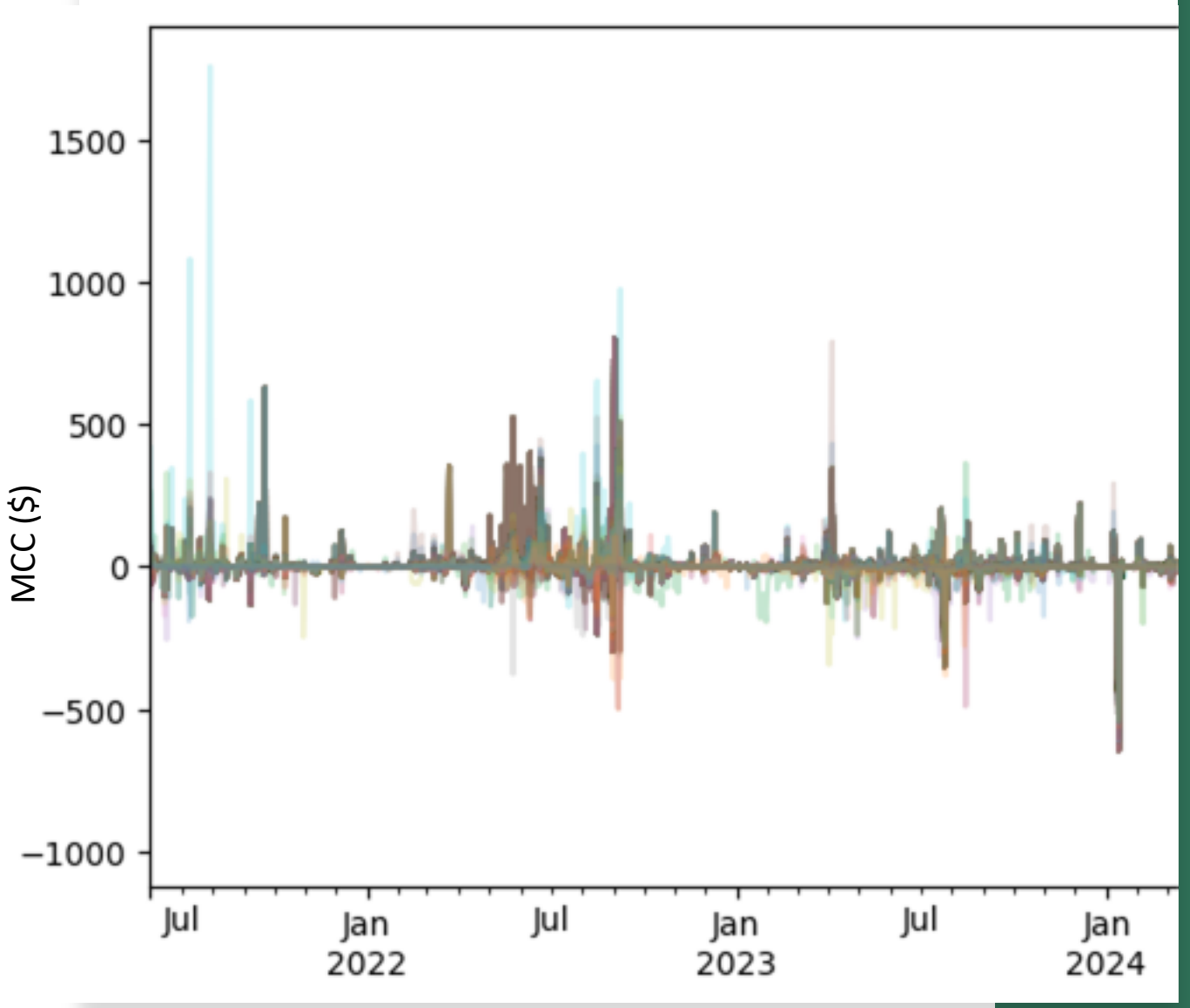
All Node Averages

- Mean absolute congestion: $13.20
- Mean signed congestion: -$0.63
- Frequency over |$20|: 13.1%



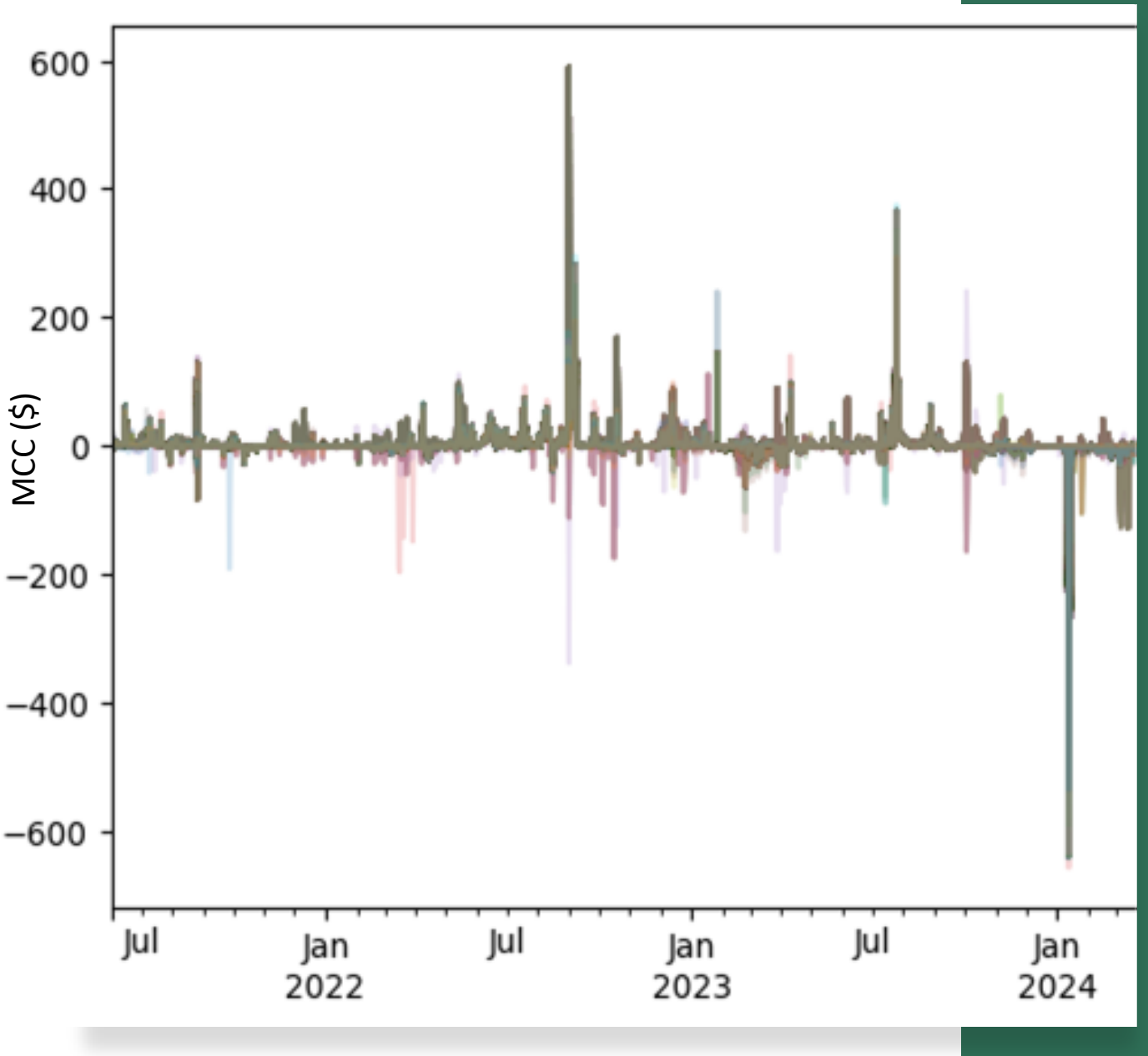
Northern California Cluster:

- **Mean absolute congestion: $12.20**
- **Mean signed congestion: $1.78**
- **Frequency over |$20|: 12.4%**
- Primary Generation: Natural Gas, Solar



Southern California Cluster:

- **Mean absolute congestion: $8.41**
- **Mean signed congestion: $2.06**
- **Frequency over |$20|: 9.8%**
- Primary Generation: Solar, NG



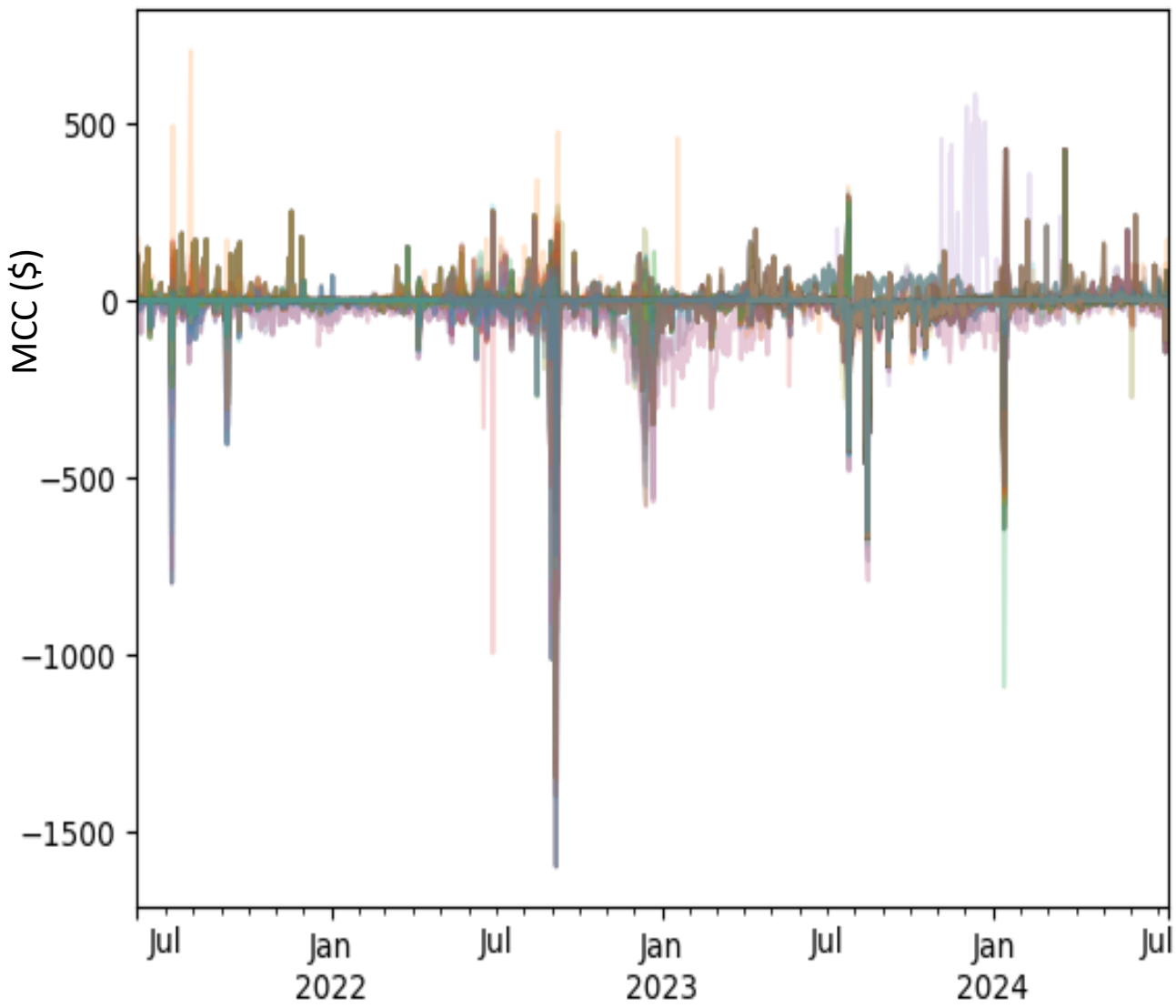
Phoenix / LV Cluster:

Mean absolute congestion: $16.11

Mean signed congestion: $-8.87

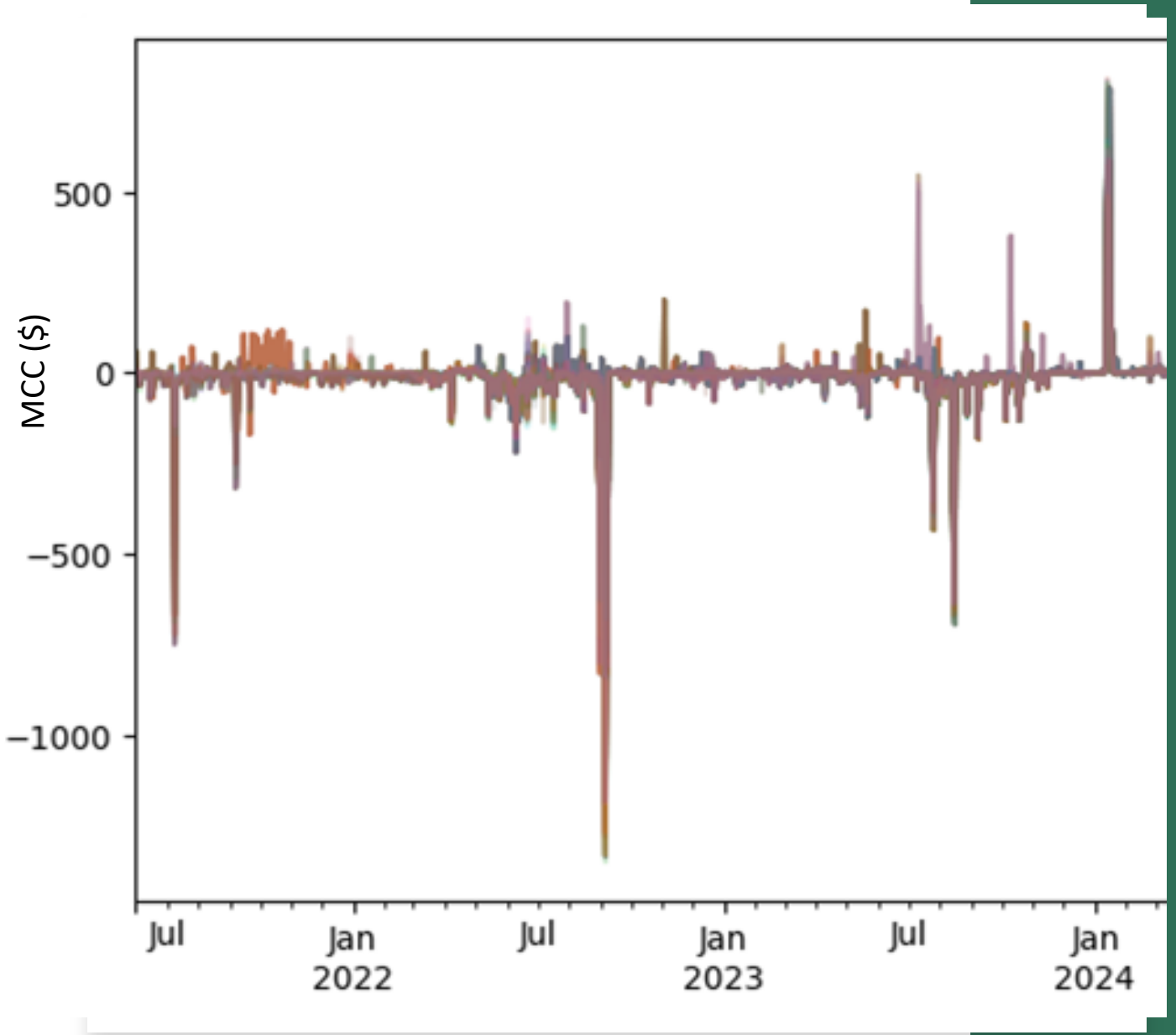
Frequency over |$20|: 15.3%

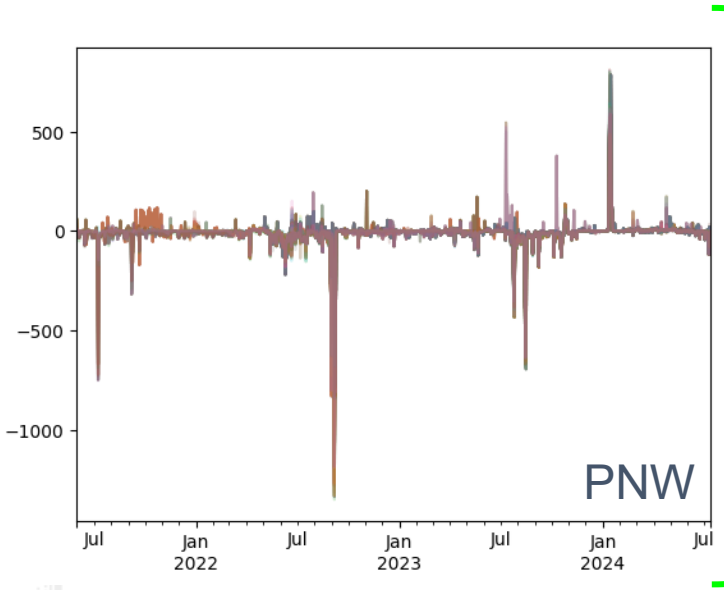
Primary Generation: Mixed



Pacific Northwest Cluster:

- **Mean absolute congestion: $26.65**
- **Mean signed congestion: $-11.02**
- **Frequency over |$20|: 24.1%**
- Primary Generation: Hydro, NG

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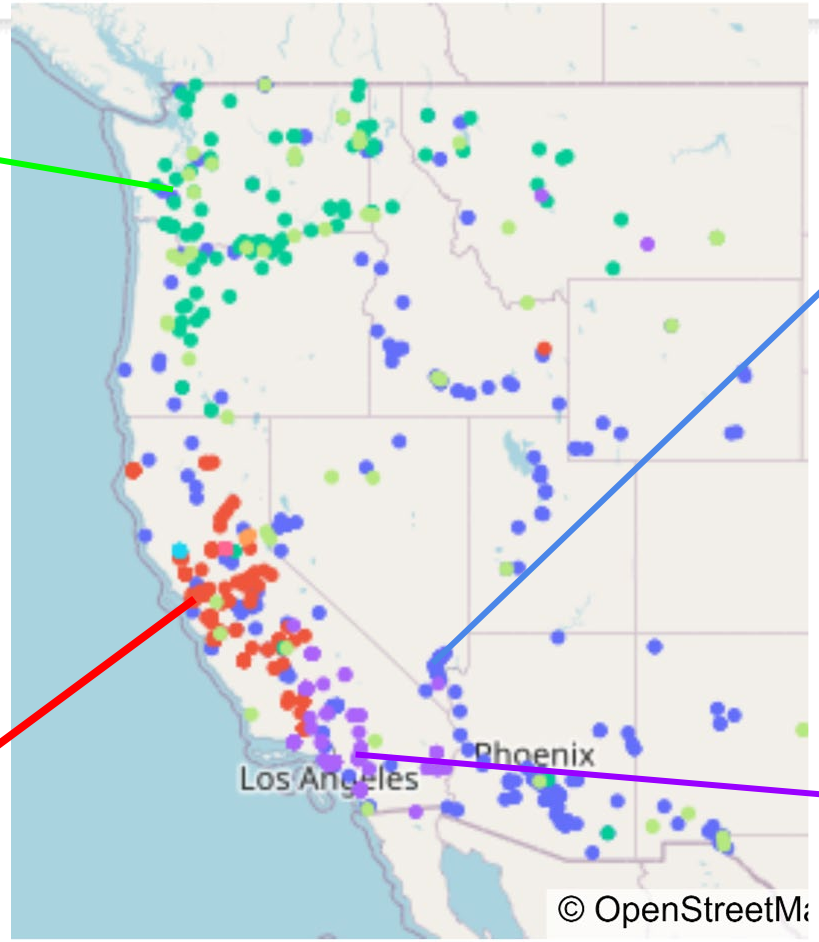
Los Angeles
Phoenix
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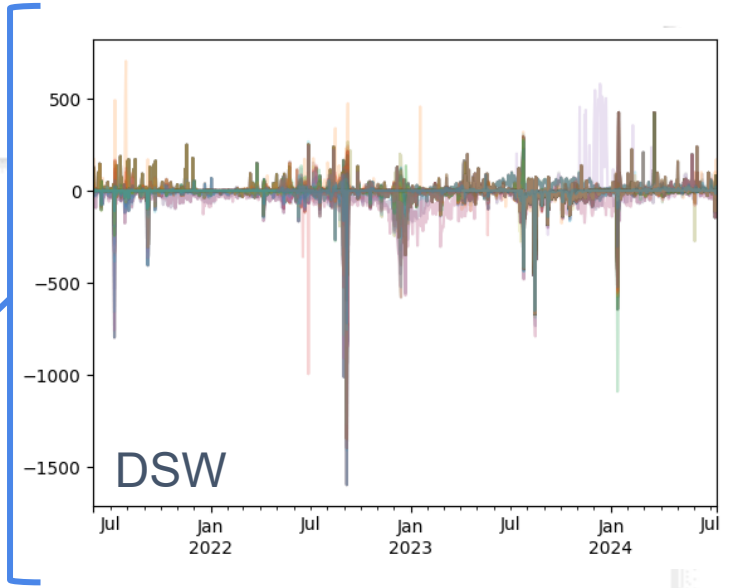
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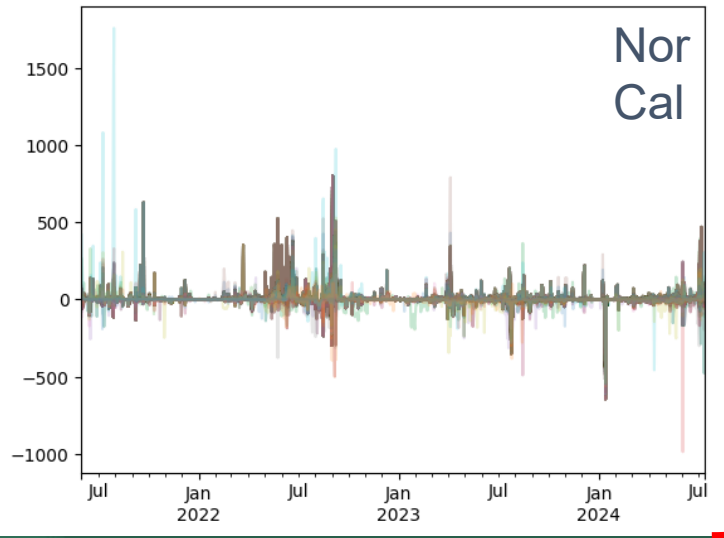
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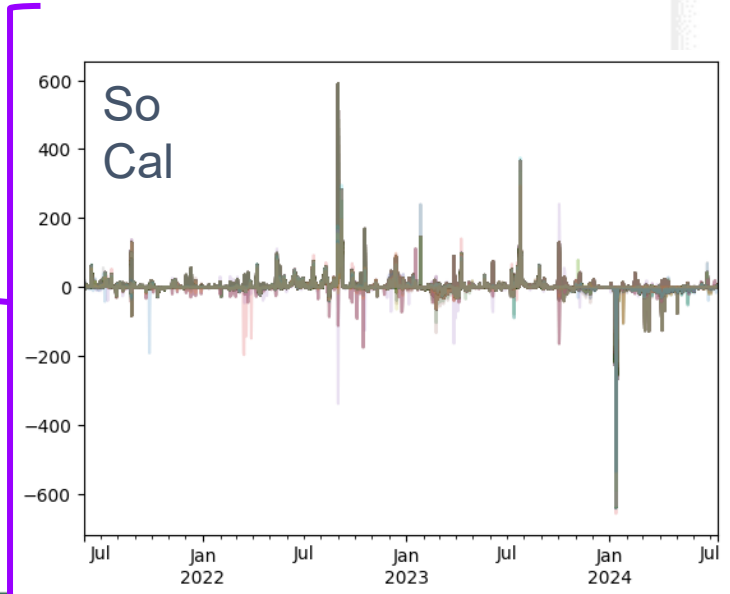
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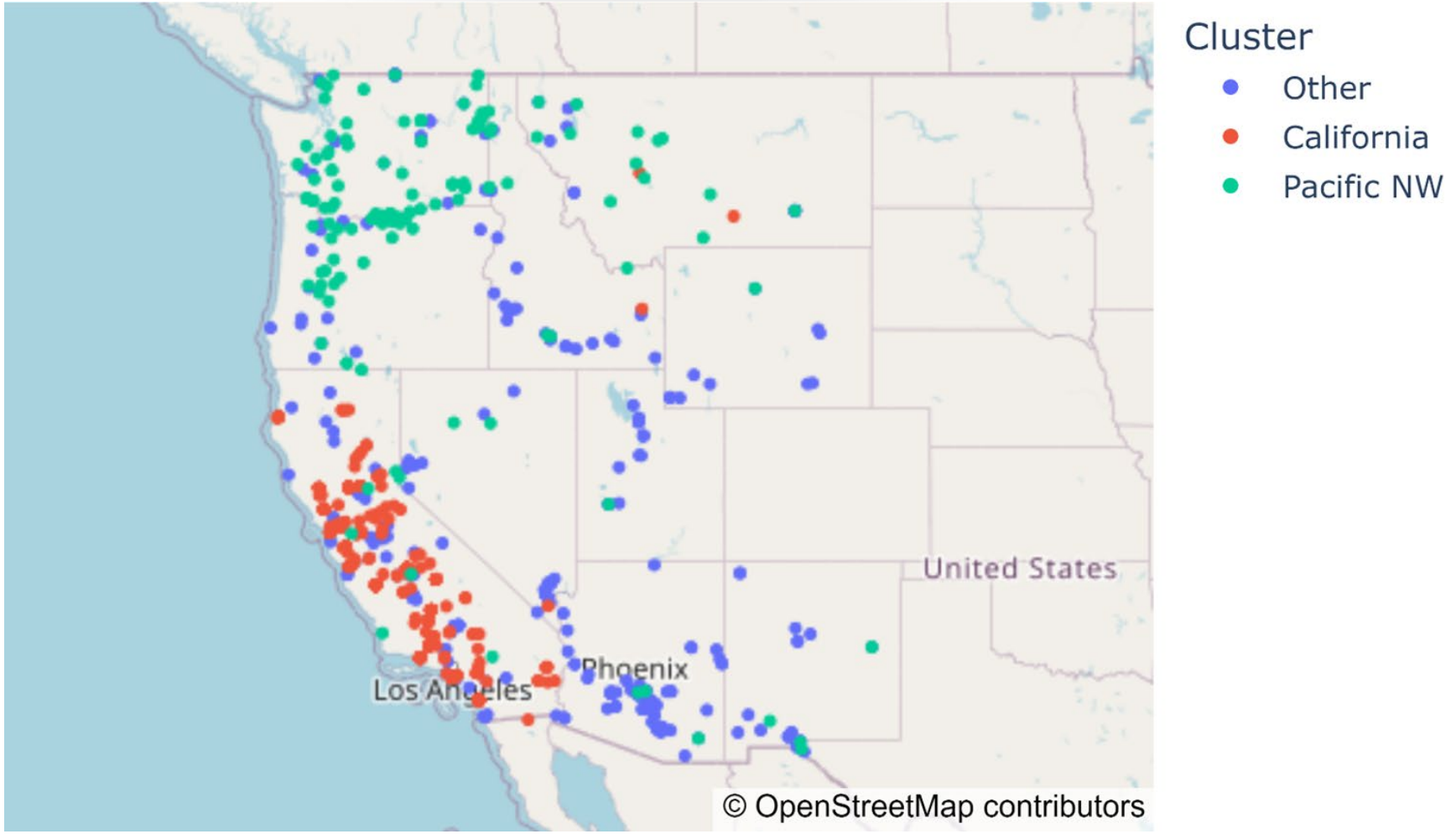
Cluster
Other
California
Pacific NW
United States
Phoenix
Los Angeles
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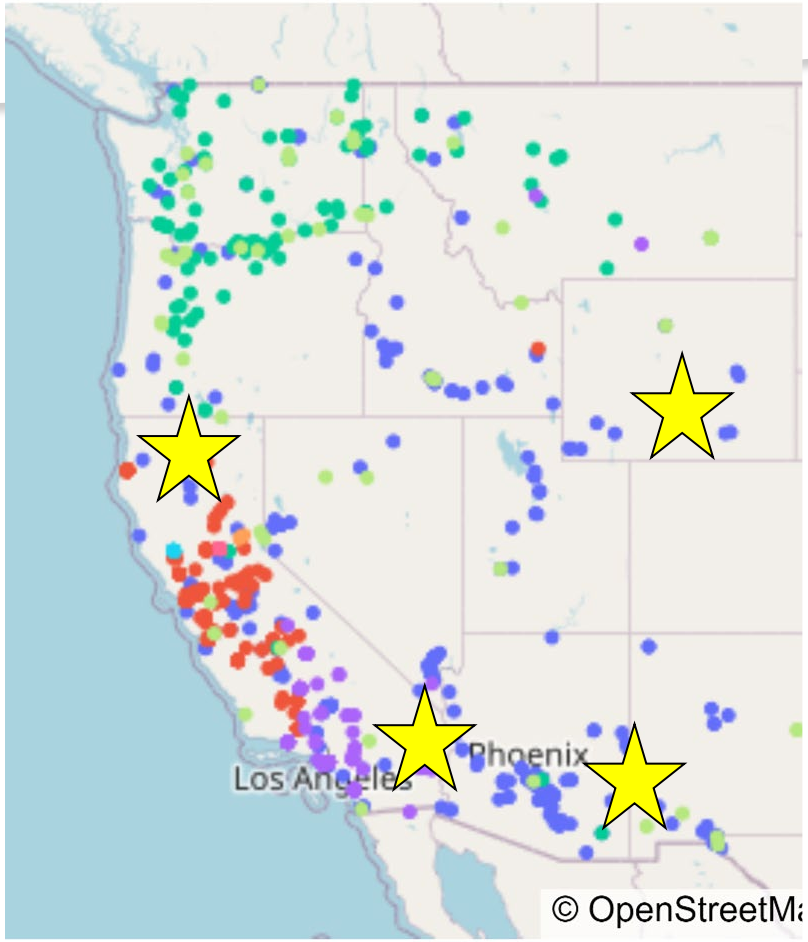
Key Takeaways

- Despite the lack of public physical transmission data, LMPs can be used to identify transmission congestion across the Western EIM footprint
- Clustering and similar analysis allows for an examination of interconnection-wide patterns
- Looking at congestion over short time frames can lead to **underestimation** of average congestion costs

Recommendations

- Interstate transmission, particularly **into and out of clustered regions,** are necessary to reduce congestion in the 15-minute market
- Analyzing different **regions** (individual BAs) and future **markets** (EDAM/M+, 5-min, etc.) with **clustering** allows for the detection of transmission patterns
- Monitor **wintertime** congestion spike as possible yearly trend
- Publicize Available Transfer Capability (ATC) data in order to verify our results



Q&A

Thank you!