Real-time air quality modeling + sensor assimilation

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RAMBOLL Bright ideas. Sustainable change.

Shair

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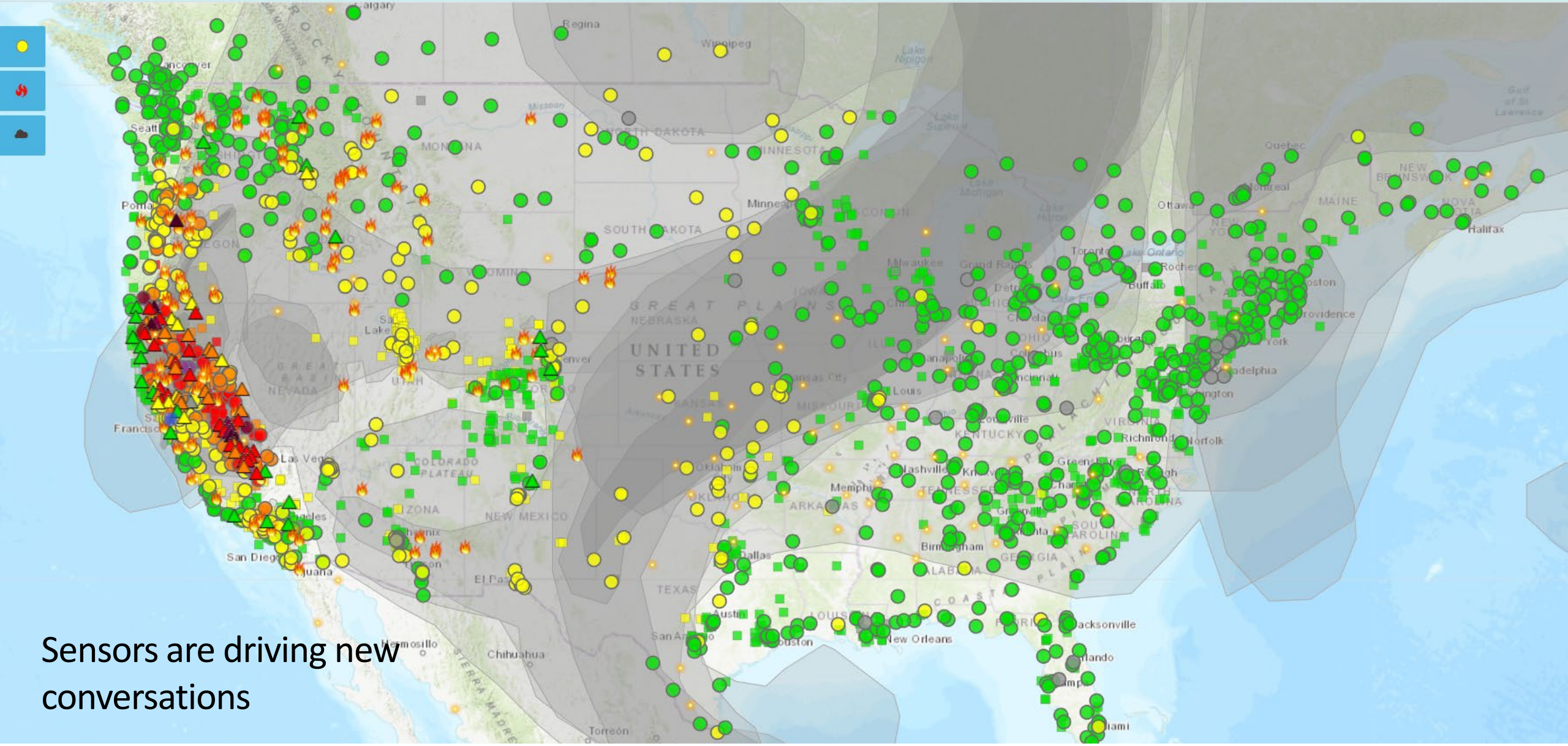
Who is Shair?

Shair is an internal startup part of Ramboll Group, the global environmental & engineering consultancy. We help connect the dots between multiple data sources in our sophisticated model that combines chemistry and physics, creating richly visualized, real-time air quality insight.

Notice: The Sensor Data Pilot adds a new layer of air quality data from low-cost sensors. Learn more here.



Sensors are driving new conversations

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Legislation is also propelling localized air quality efforts

- California Assembly Bill 617 (AB617) is a community-driven process to address air pollution impacts in environmental justice communities
- Funding supports community air monitoring and community-driven emissions reduction planning

New roles for air quality modeling

Attention is shifting from a regional perspective to a more localized perspective.

New measurement techniques are helping drive this shift (whether low-cost sensors or mobile laboratories) – but analysis and diagnosis of this data can be more challenging

Real-time measurements identify **what** is happening on the ground at a high-resolution, but not **why**

Models answer **why** – but at high temporal and spatial resolutions, datasets are disparate and difficult to put together effectively

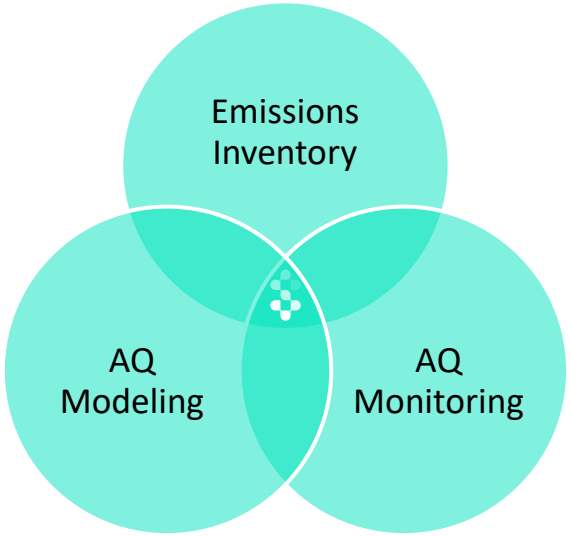
Helping answer questions on air quality, like:

What sources are contributing to the concentrations we are measuring?

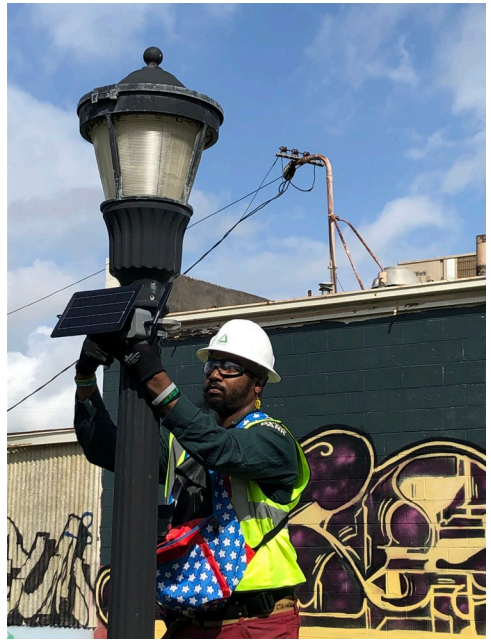
A new foundation from **combining datasets**

Putting modeling, monitoring, and emissions inventories together and aligning the datasets across higher spatial and temporal resolutions creates a new foundation of analyses on existing data.

Adding new datasets, like real-time traffic and low-cost sensor networks, enables new types of investigation – and answers new questions.



Pilot project Richmond, CA



70

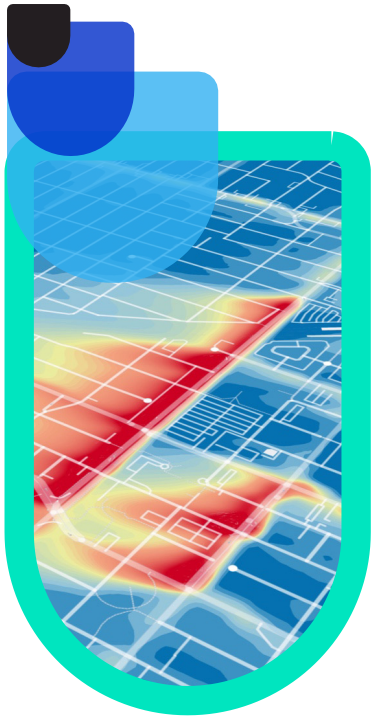
- Gravimetric PM2.5/PM10 samples for metals screen
- Workforce development

50

- Clarity Nodes

1

- Real-time model and web application



What **is** Shair?

Emissions

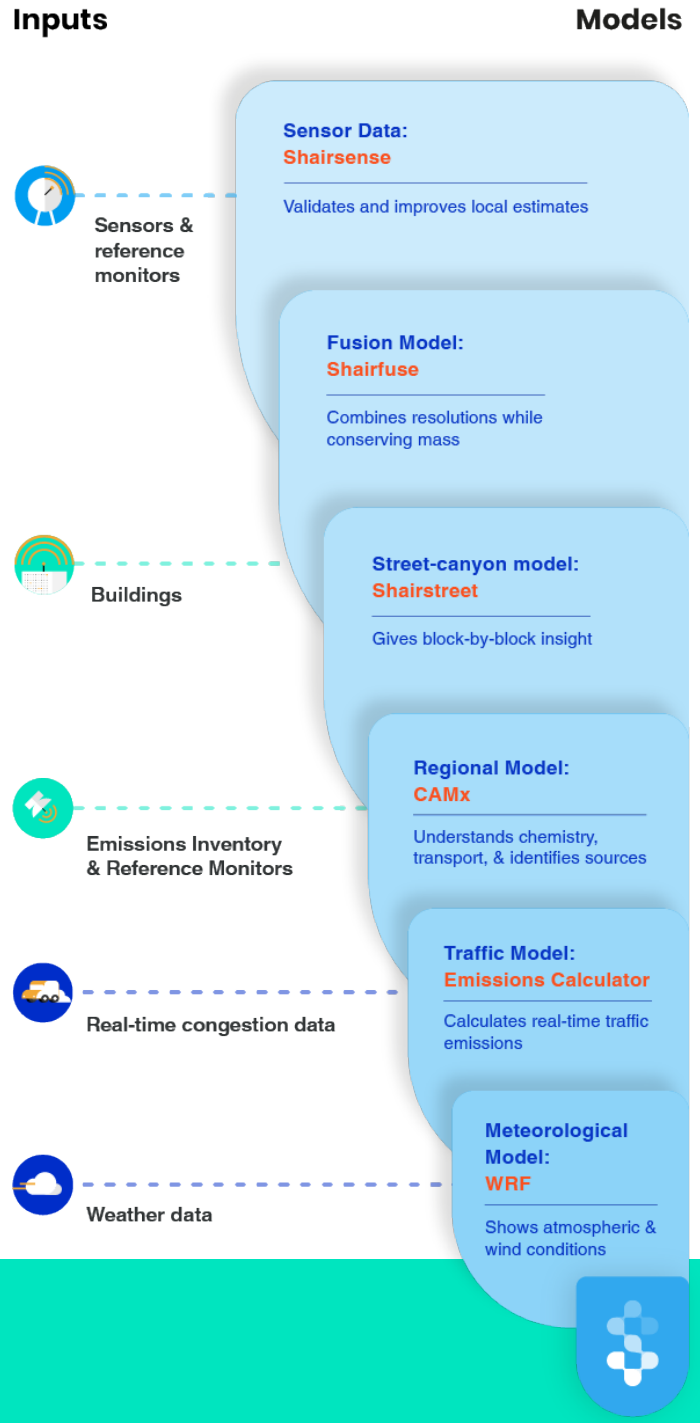
- *Real-time:* Traffic API with Travel Demand Model creates congestion data informing emissions
- *Static (if unavailable in real-time):* Disaggregated Emissions Inventories across space and time

WRF and photochemical air quality models (CAMx + Shairstreet) estimate dispersion

Regional and local models are fused together for consistency, 10x10m resolution

Adjusted and validated by measurement

docker kubernetes argo



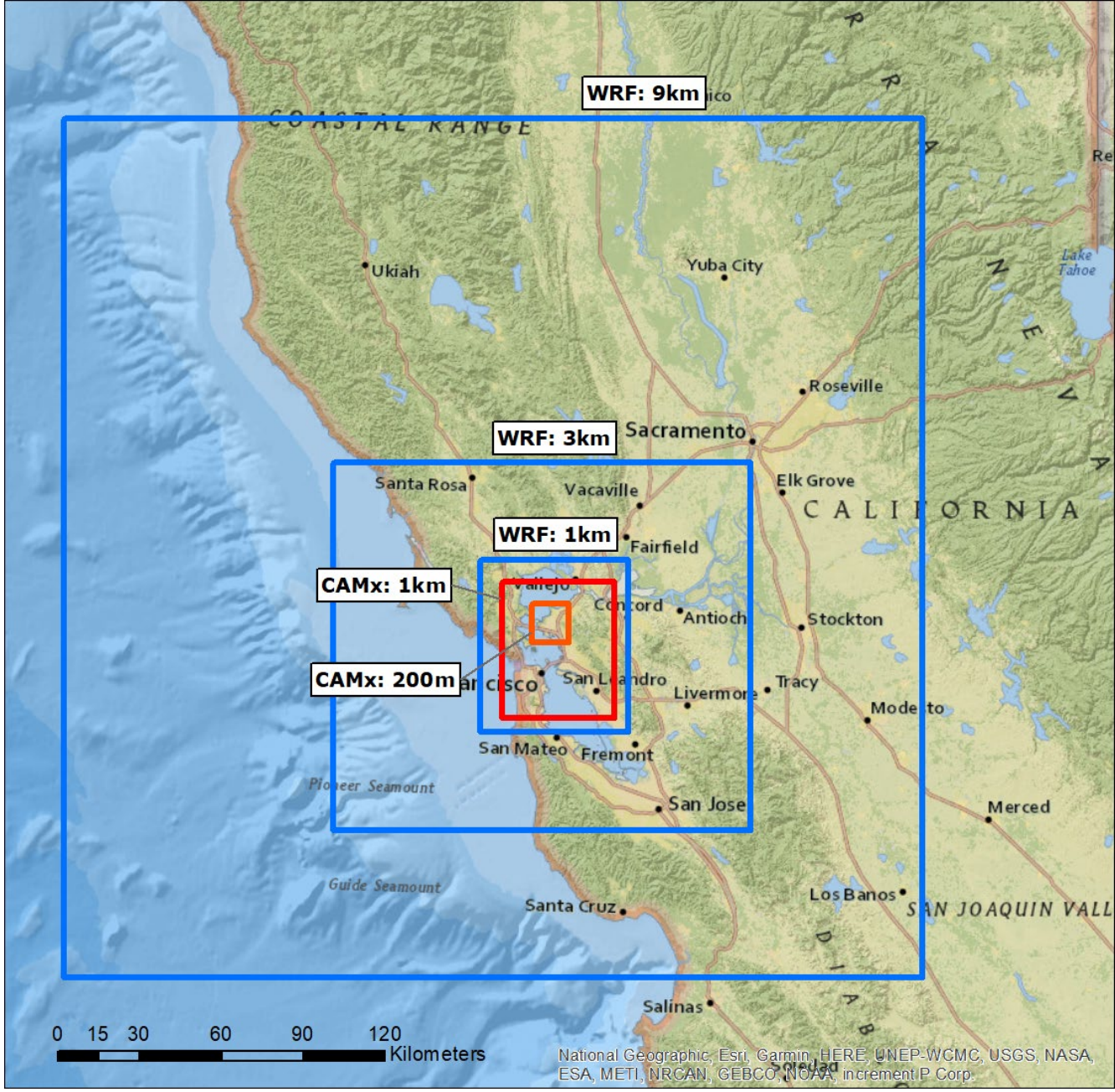
Shair Configuration in Richmond

Meteorology

- WRF NAM forecast refreshed every 6 hours
- Nested grids: 9km, 3km, and 1km resolution

CAMx

- 1km and 200m grids
- Fast chemical scheme for O3-NO-NO2
- Wet and dry deposition with ZHANG03 model
- Tag emissions by source category for source apportionment
- Latest emissions combined with previous hour dispersion results



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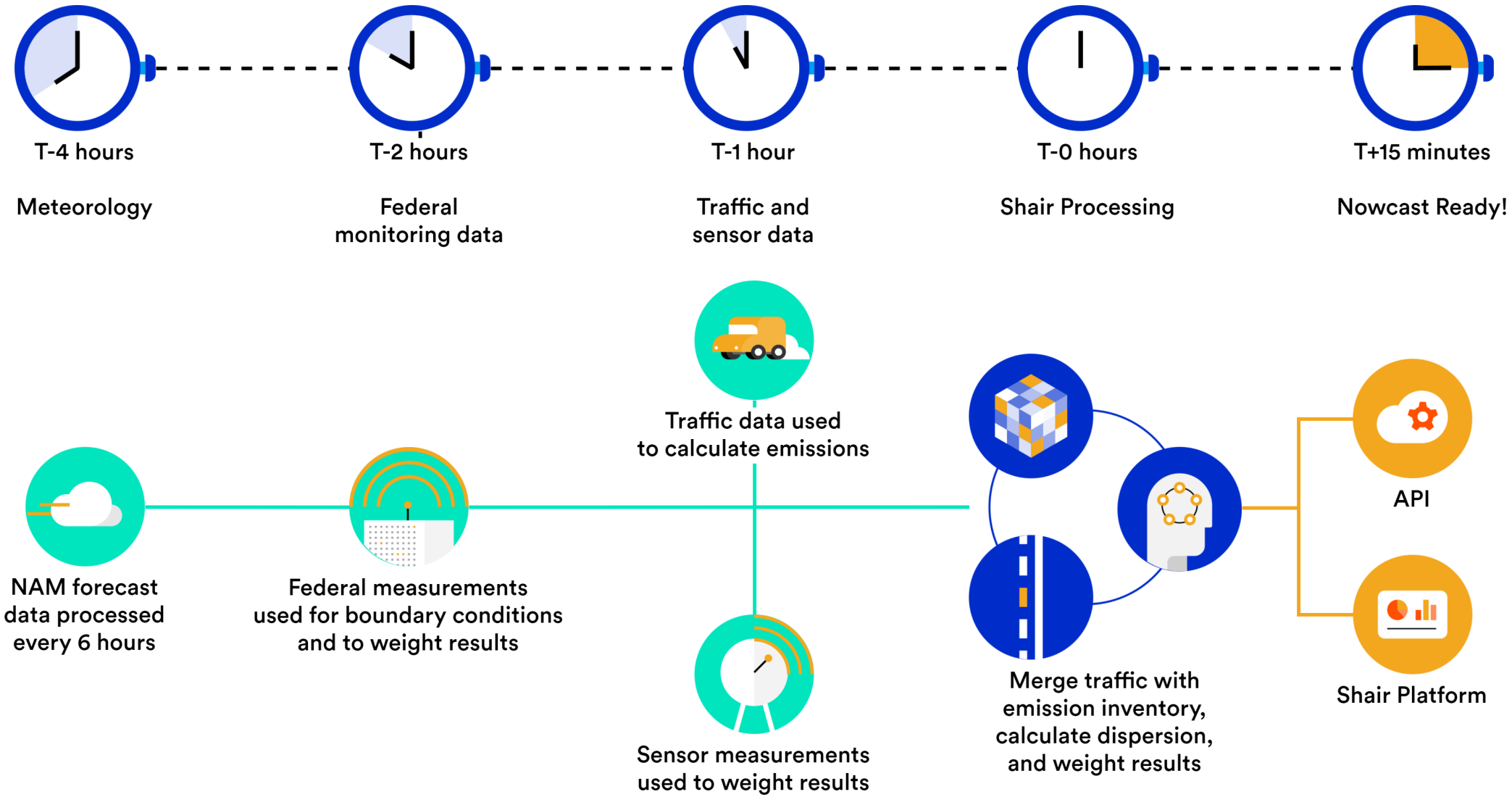
Nowcast Data Timing Summary



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Real-time Traffic Emissions

Mobile emission inventories (EMFAC, MOVES, COPERT)

Open Street Map data

Realtime speed data from an API

Travel demand model or historical counts and speed data

Retrieve all streets in an area

Calculate real-time traffic flow

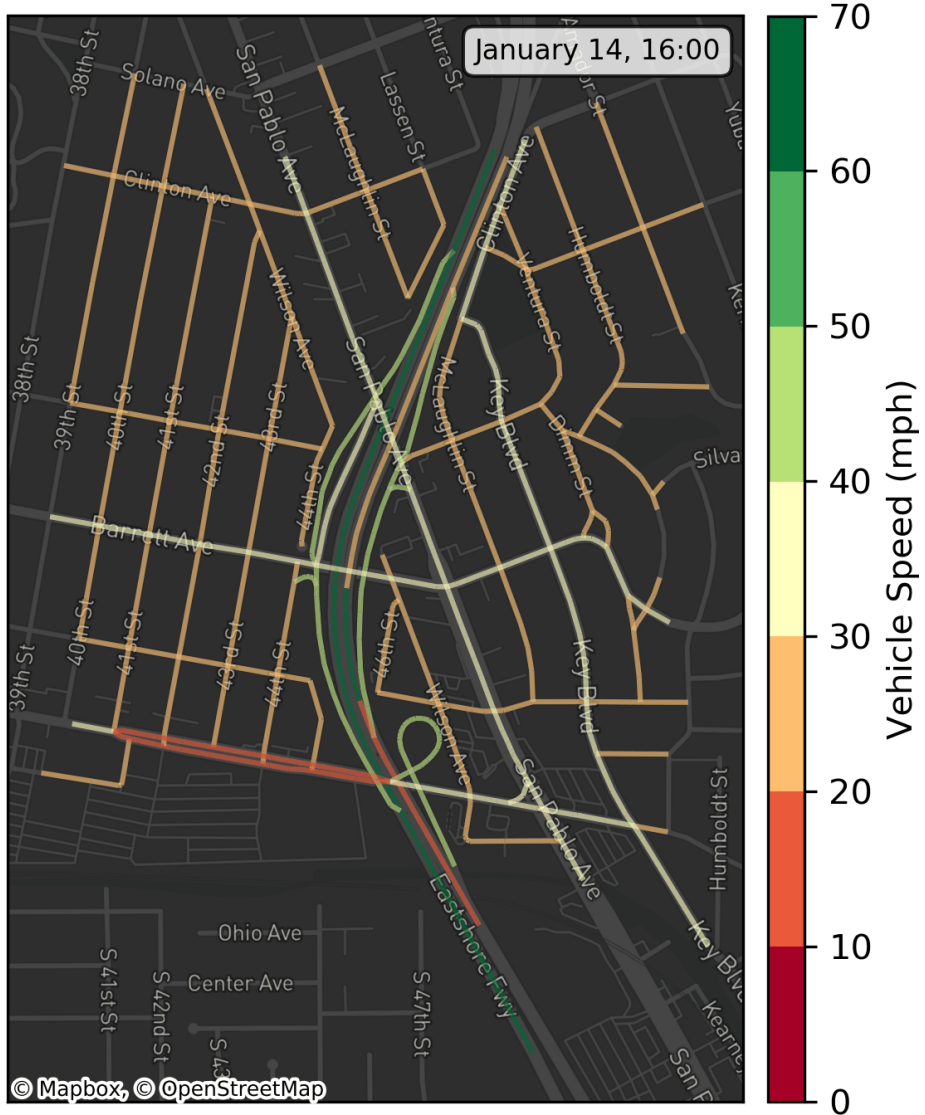
Merge data

Traffic emissions

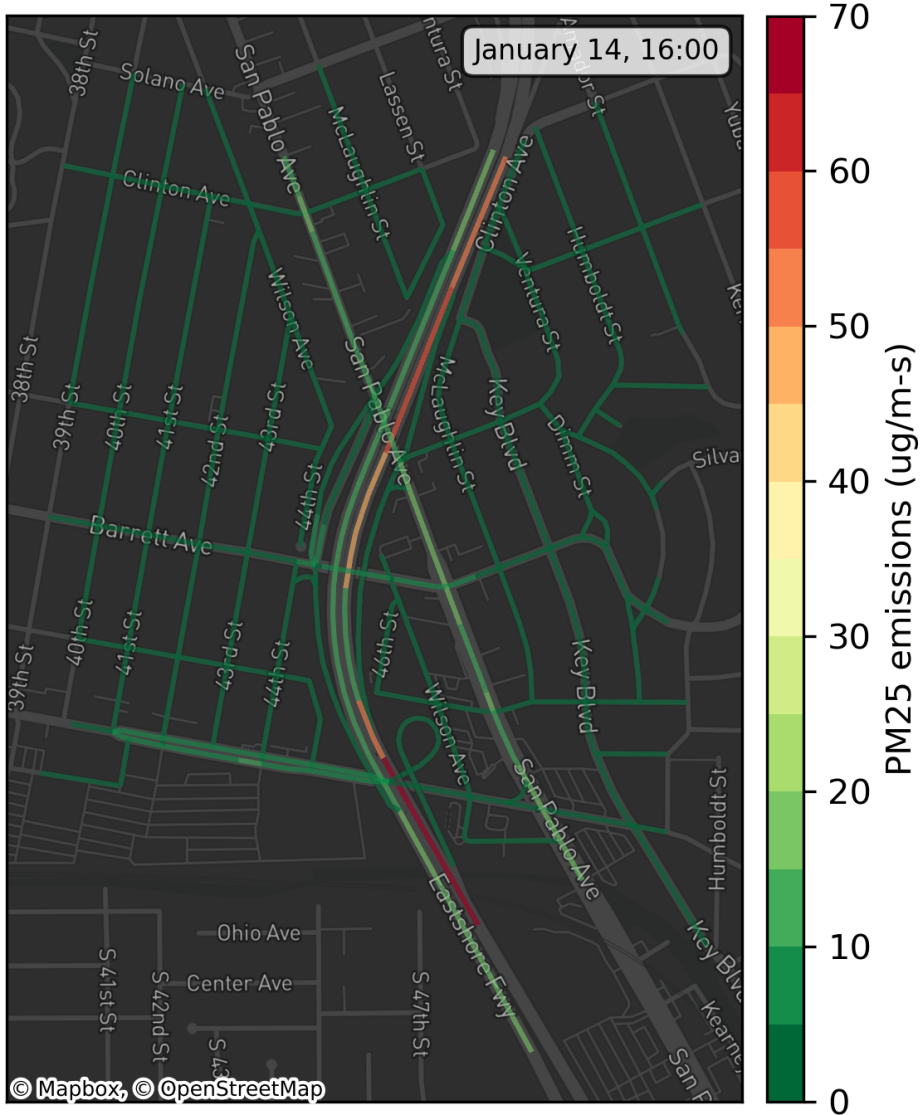
358,269 Modeled Road Links in the Bay Area

Real-time Traffic Emissions

Vehicle Speeds



$PM_{2.5}$ Emissions



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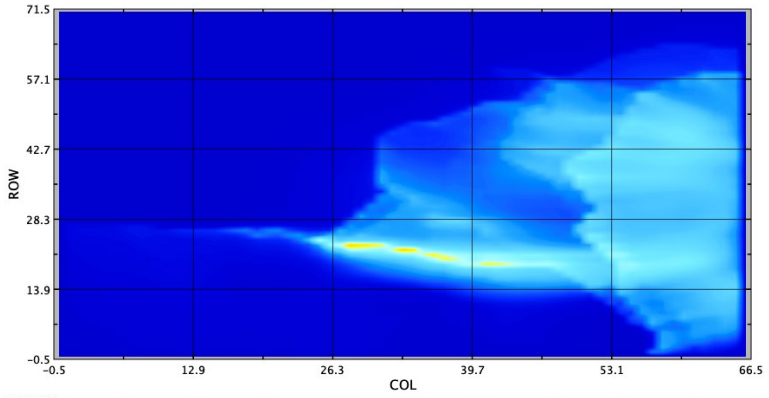
Fusing local and regional models

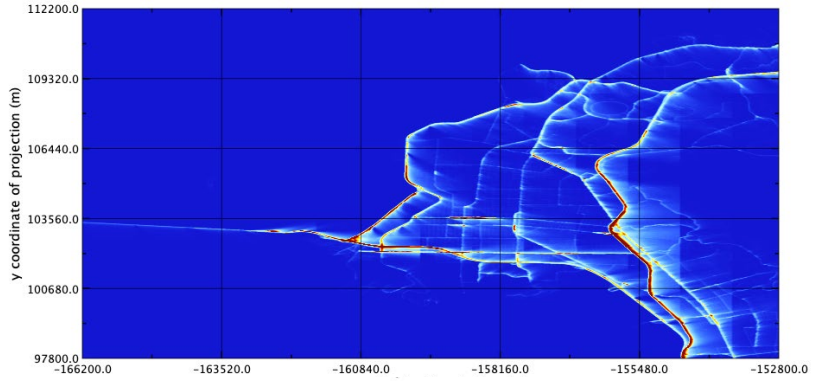
Avoiding double-counting of traffic concentrations.

- Shairstreet is a 10m resolution line source dispersion model and provides high resolution spatial variability near roadways
- CAMx has the exact same traffic emissions but aggregated emissions at 200m and can accumulate pollutant mass in gridcells far away from the line sources
- CAMx and Shairstreet are fused together using a mass redistribution scheme with neighboring cells

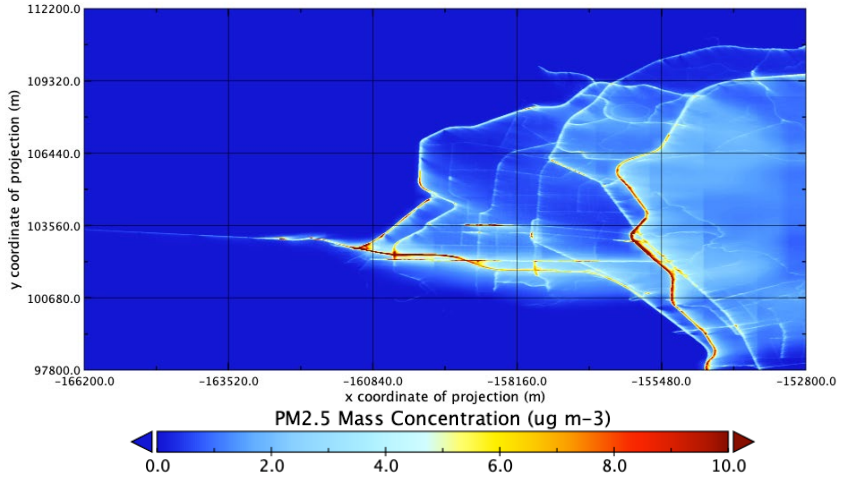
CAMx Traffic $PM_{2.5}$



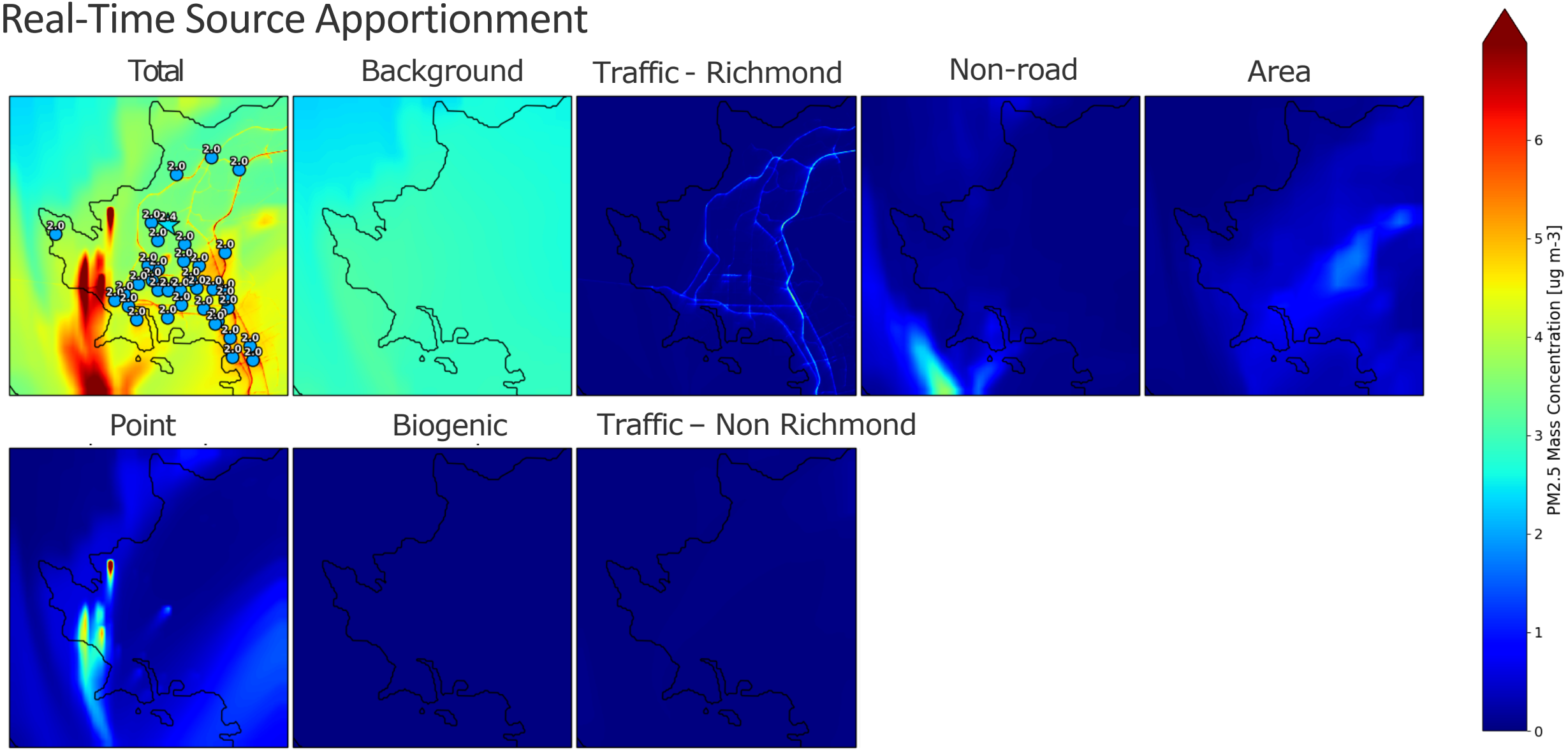
Shairstreet $PM_{2.5}$



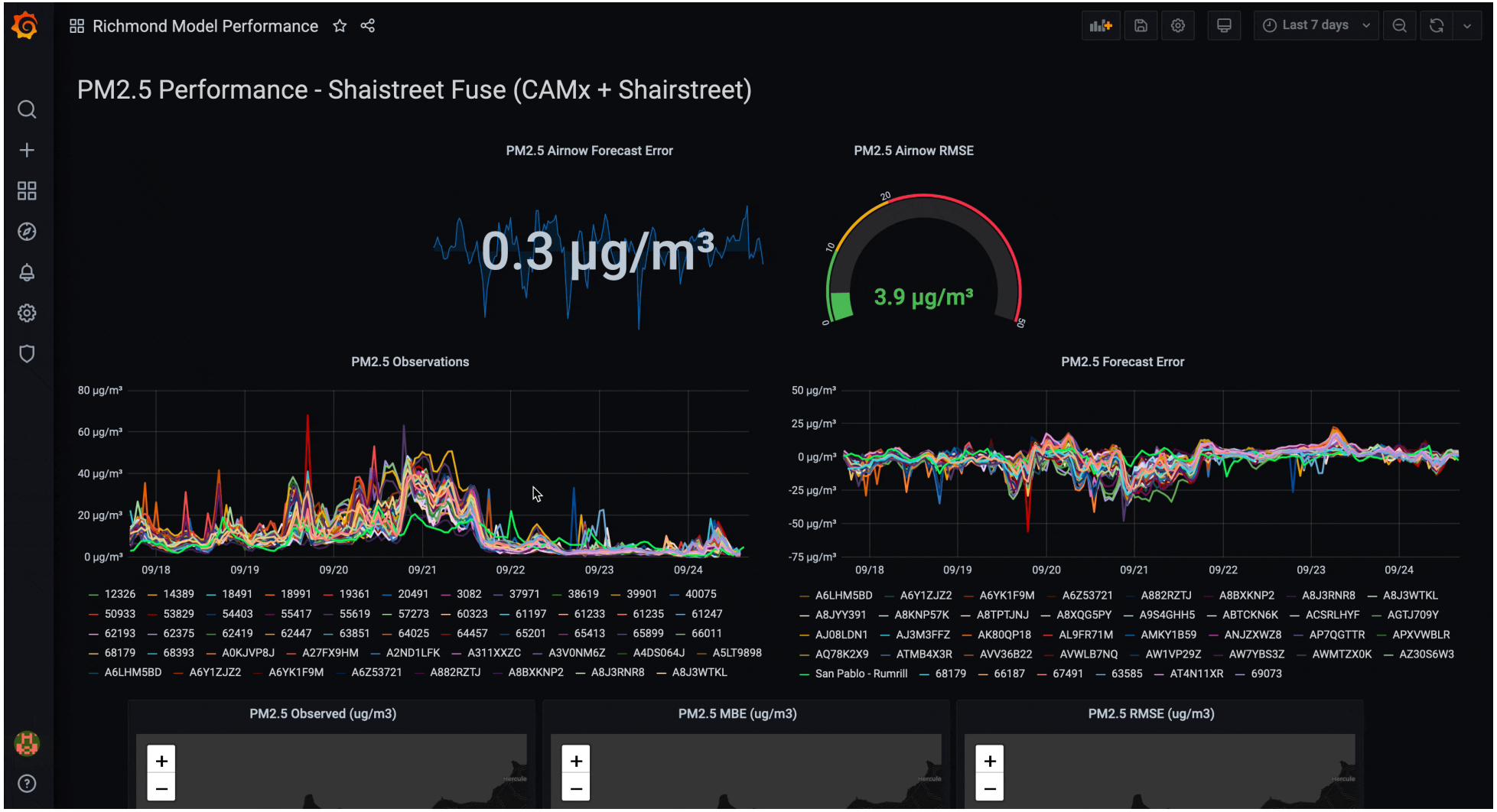
Fused $PM_{2.5}$



Real-Time Source Apportionment



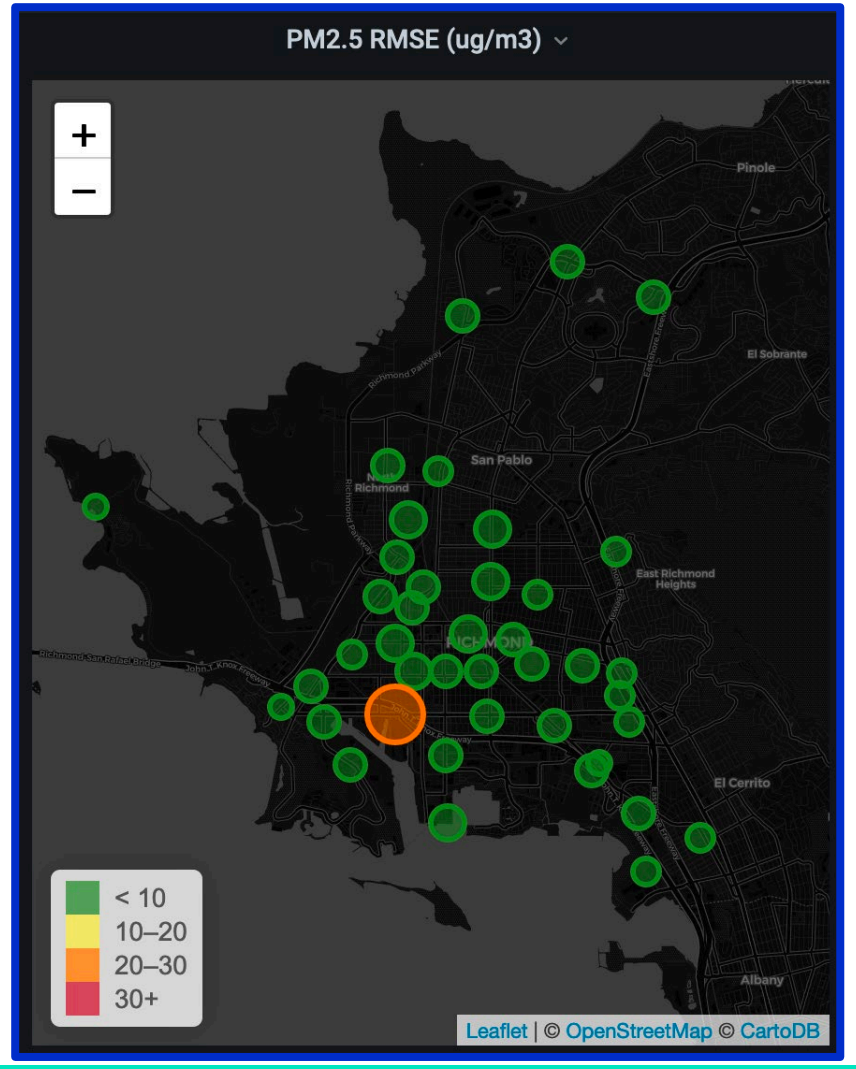
Dealing with model bias



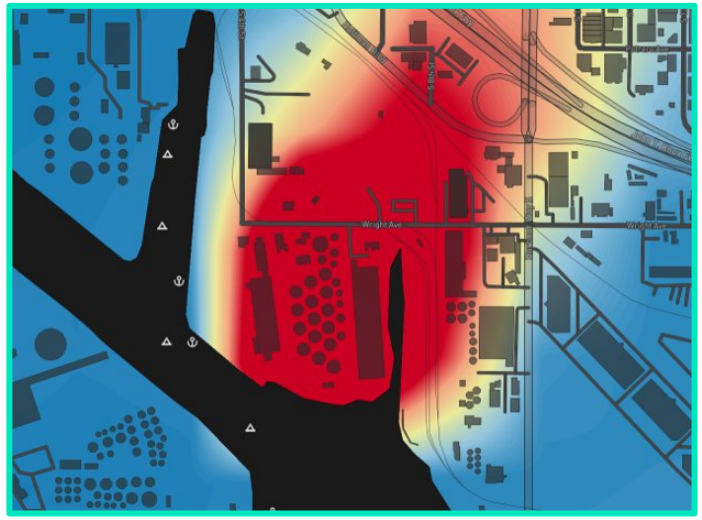
- Live model performance dashboards
- Identify patterns from sensors that are consistently different from model
- Improve static emission inventory

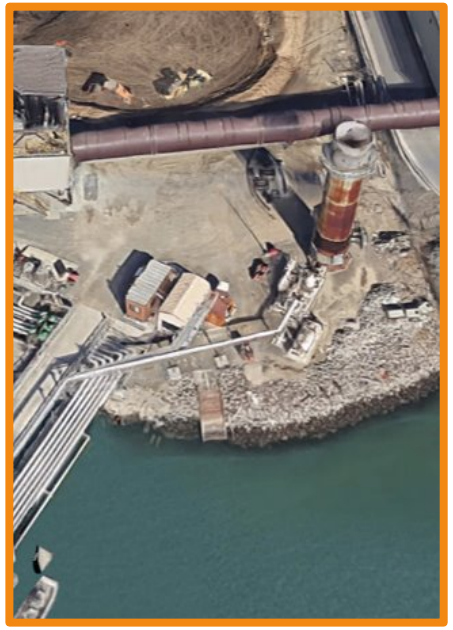
Dealing with model bias

December 2019 RMSE



Identified a stack parameter error in the air district's emission inventory database that was then fixed because of Shair.





Answering questions like…

What source(s) are responsible? By how much?

Can I really *see* what air quality is like anywhere, not just at sensor locations?

Is my emissions inventory correct?

Are mitigations working?

Under what conditions are we seeing higher impacts? Can I get alerted when we see those conditions?

Local scale exposures?

Examples and Demonstration

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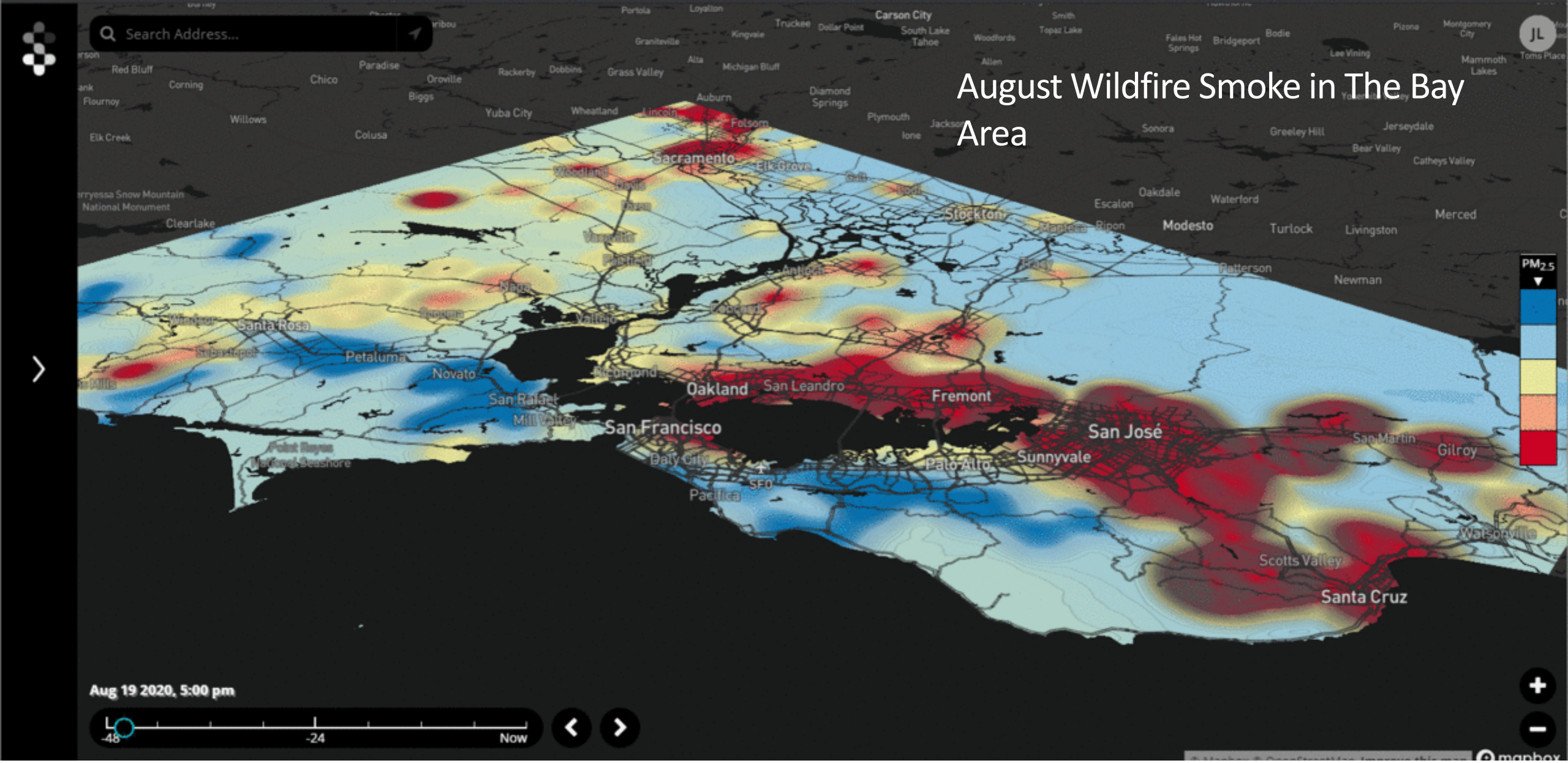
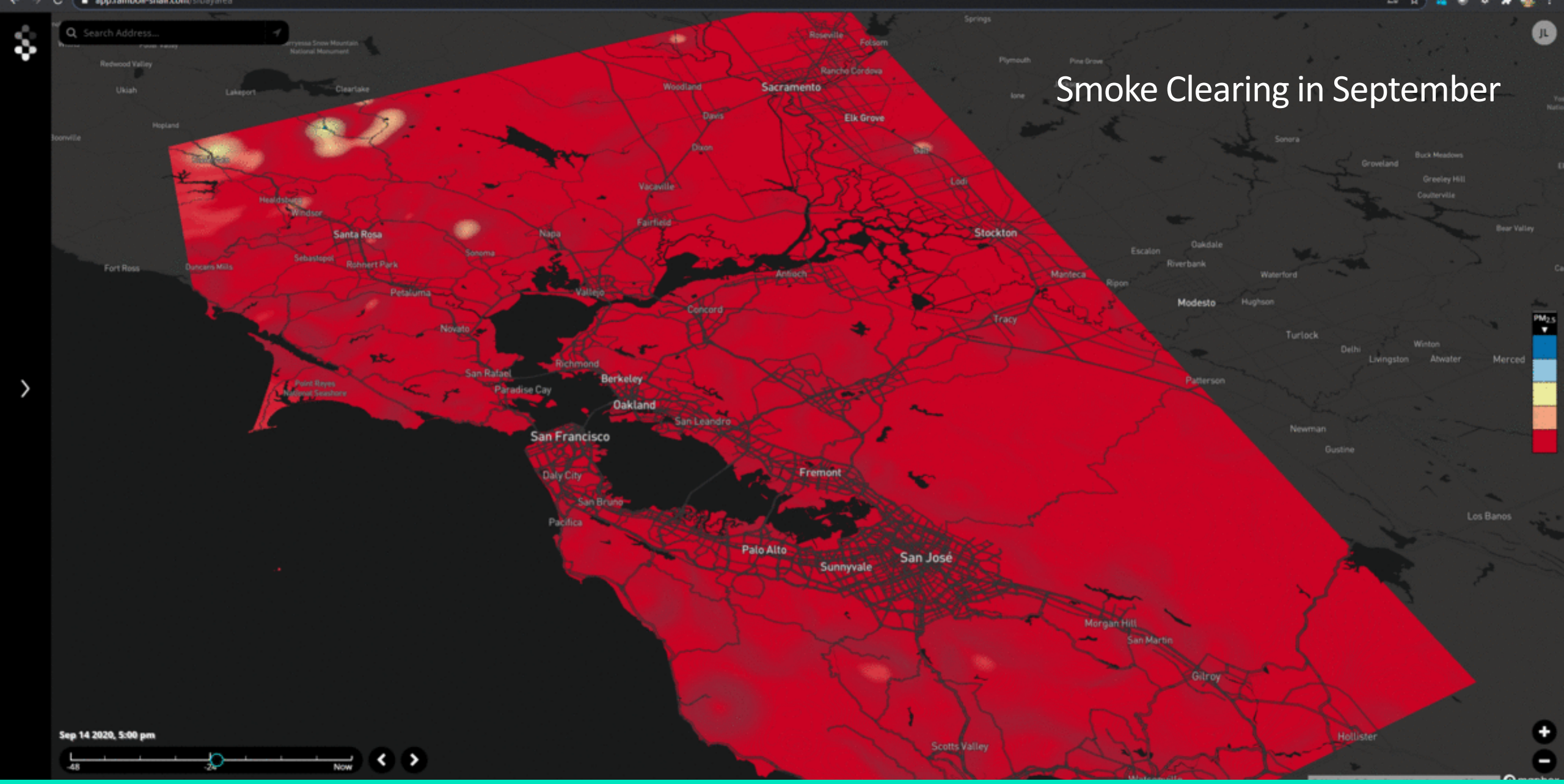
August Wildfire Smoke in The Bay Area



Smoke Clearing in September



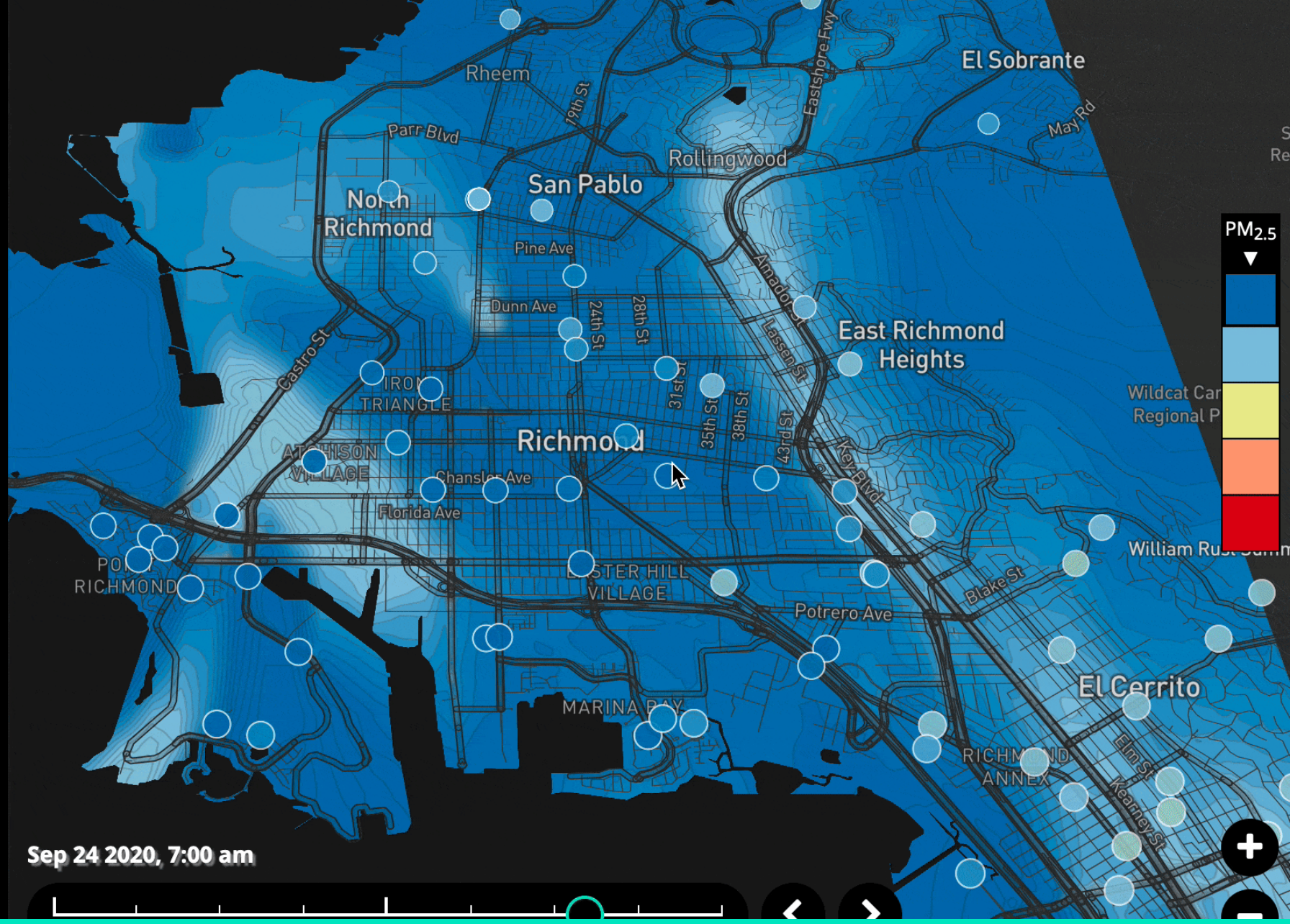
Not seeing your city or area?

CITY: Richmond, CA

MODE: Nowcast

Source Contribution

Please click a location on the map where you would like to see source contribution data.



Demonstration

Explore the public map to see how City of Richmond, CA now has real-time access to clearly visible and highly actionable air quality insights.

https://app.ramboll-shair.com

or

shair.ai

Questions & Open Discussion

Thank you!

Please reach out with any additional questions or follow-up!

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Supplementary materials

Typical questions/comments received

- What sensors do you use? How many do you need?
- What do you need to run Shair?
- Why isn’t Shair coverage nationwide or global?
- How is Shair different from other air pollution maps (like global data providers or machine learning models)?
- Can Shair be used for regulatory purposes?

What’s next for Shair?

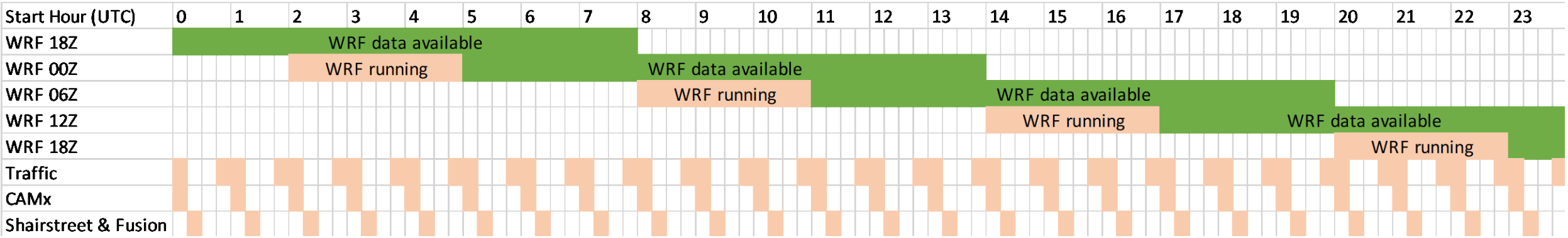
Technical Developments

- Real-time shipping emissions using AIS data
- Improve sensor data assimilation technique
- Improve front end (for example, wind vectors)
- Forecasting not only for nowcast but for next 6 hours

Looking for partnerships!

- We want to help more communities asking questions about their air quality
- Want to work with Shair data?
- Want to work with Shair models?
- Want to see Shair in your area?
- Let’s talk!

Detailed Breakdown of Shair Model Timing



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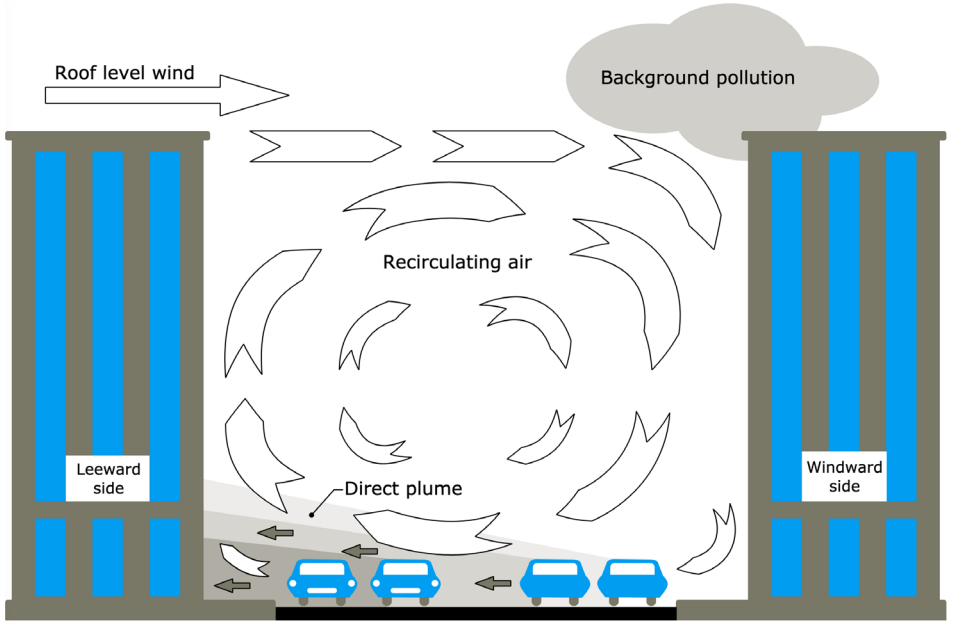
Shairstreet Modeling

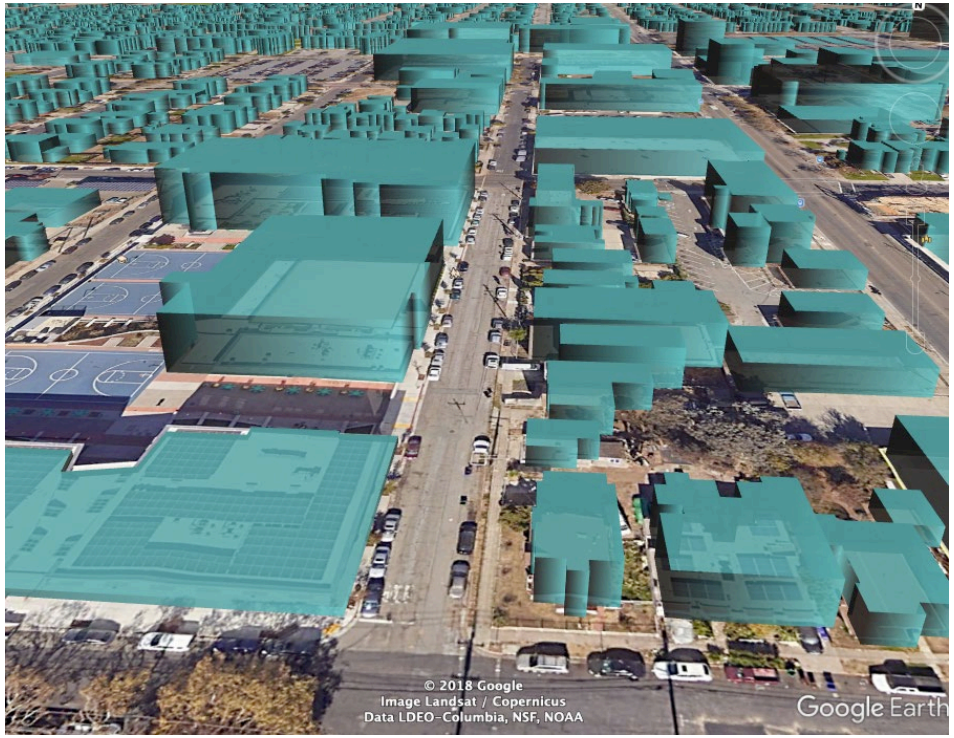
Fine scale resolution of road emissions

1. Street canyon model

Calculates additional recirculation contribution for road links that have street canyon-like geometry, using wind speed and direction at top of the canyons. Takes into account vehicle generated mechanical turbulence.



Modeled buildings in Richmond (view from Chanslor Ave and 9th St)



Shairstreet Modeling

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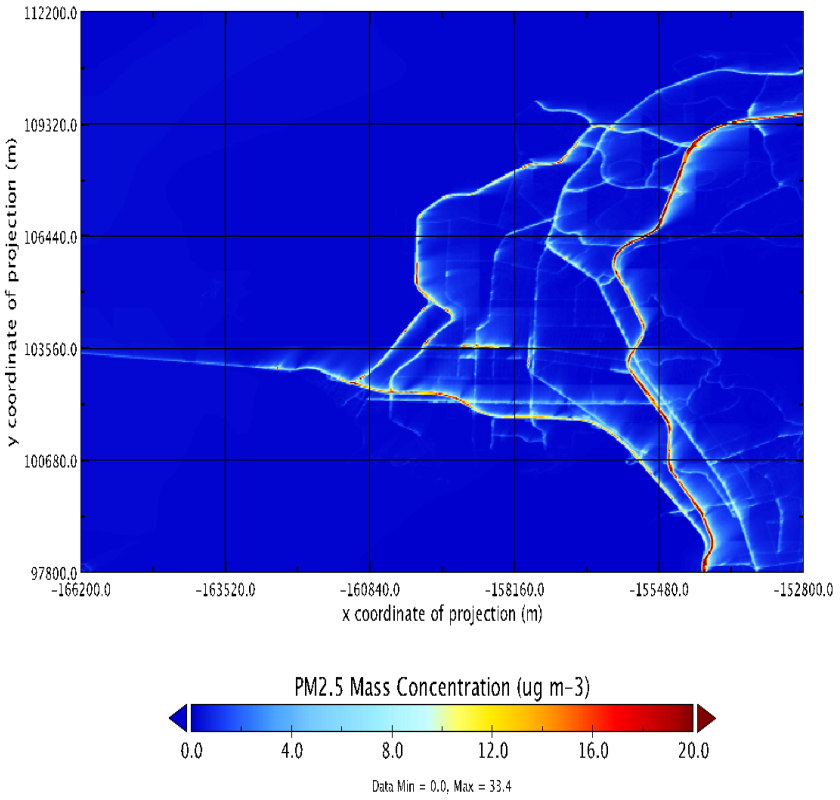
Calculates additional recirculation contribution for road links that have street canyon-like geometry, using wind speed and direction at top of the canyons. Takes into account vehicle generated mechanical turbulence.

2. Line source dispersion model

Road links are modeled as line sources based on Venkatram and Horst 2006 approximate Gaussian dispersion solution at **10x10m resolution**.

3. NOx chemistry model

Simplified NO-NO_2-O_3 model based on During et al. 2011, with parameterized mixing times based on street-canyon geometry.



$$NO + O_3 \rightarrow NO_2 + O_2 \ (k)$$
$$NO_2 \rightarrow NO + O_3 \ (J)$$

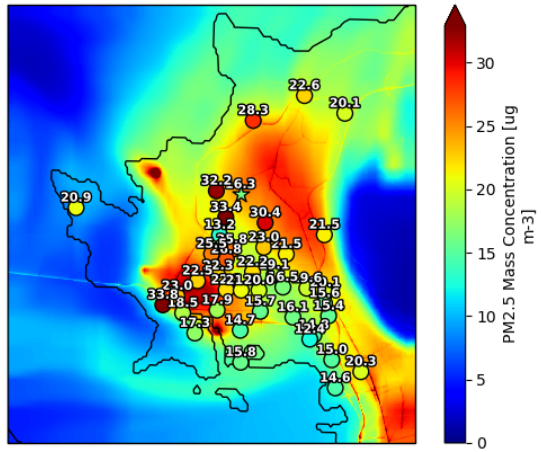
Reaction and photolysis rates, k and J, taken from CAMx 200m grid along with background NO_x and O_3

PM2.5 November 11th 2019 6:00pm PDT

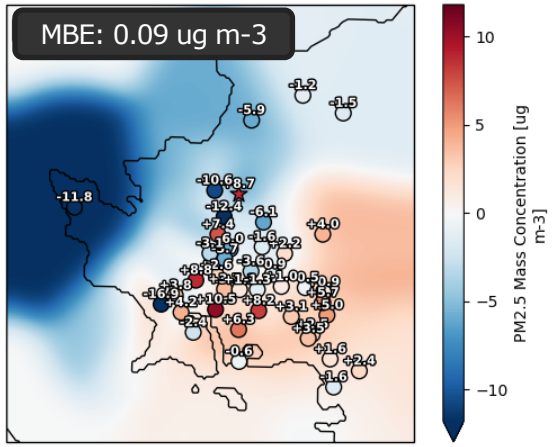
Sensor Integration

- Latest Clarity sensor, PurpleAir, and Airnow monitor data pulled
- Measurement data undergoes internal quality control checks and adjustment
- Objective analysis via Barnes interpolation is used to assimilate sensor measurements

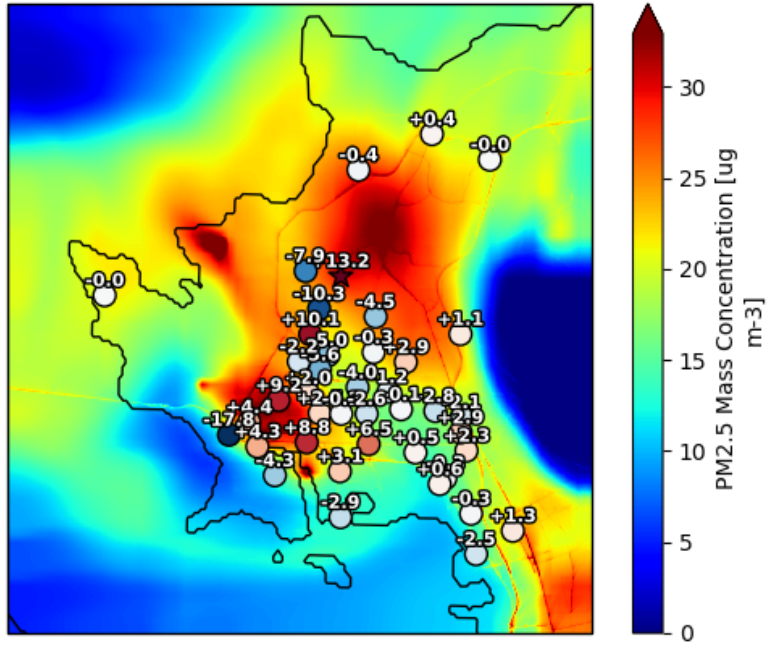
Raw model + sensors



Interpolated model error



Assimilated map



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