Shair:
Real-Time Air Quality Modeling Driven by Measurement Data

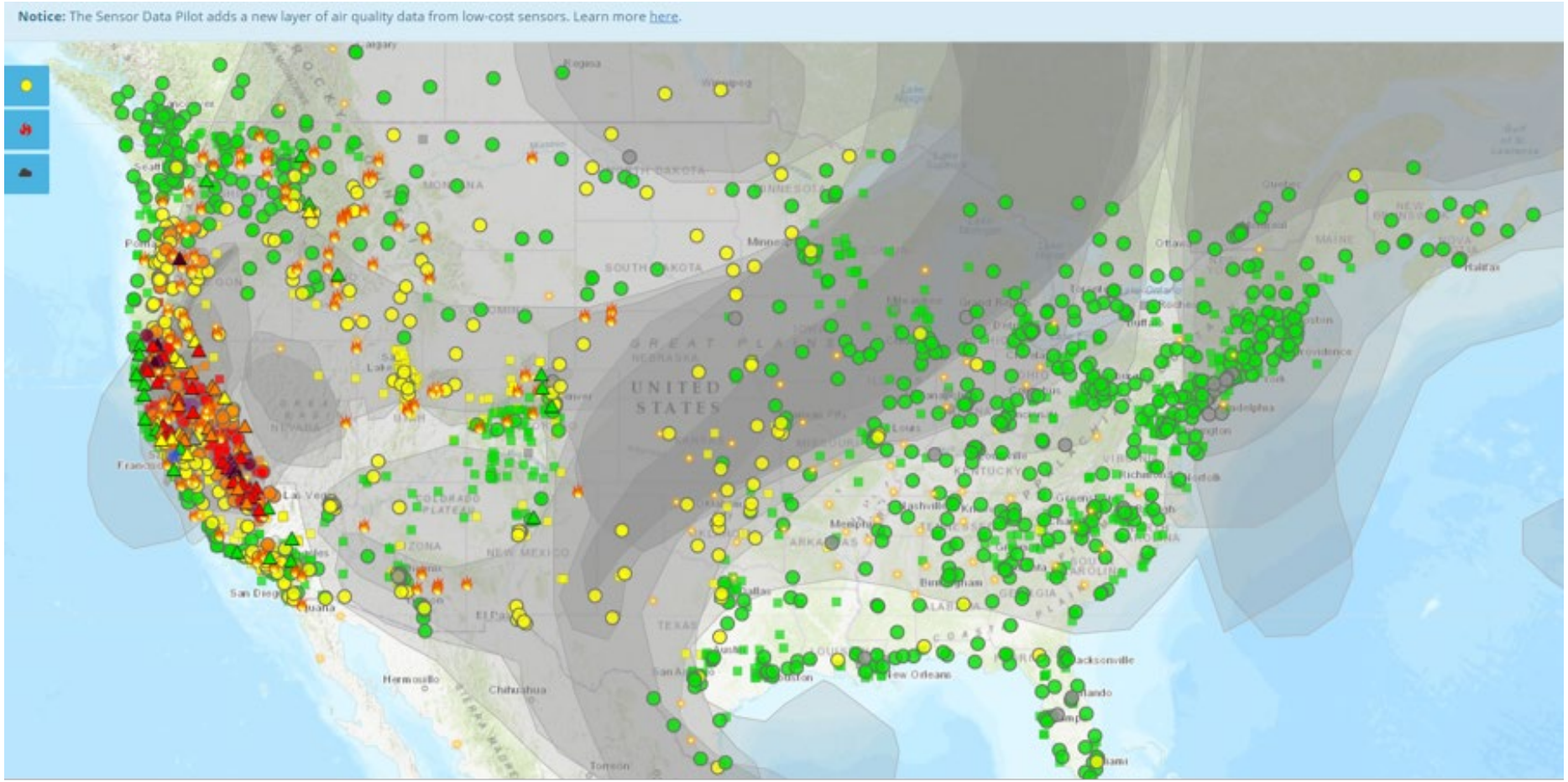
Ali Akherati, PhD
Rei Zhang
Mike Dvorak, PhD
Farzan Oroumiyeh, PhD
Martin Parsons
Shari Libicki, PhD
Greg Yarwood, PhD

2022 National Ambient Air Monitoring Conference
August 22-25, 2022
Pittsburgh, Pennsylvania, USA

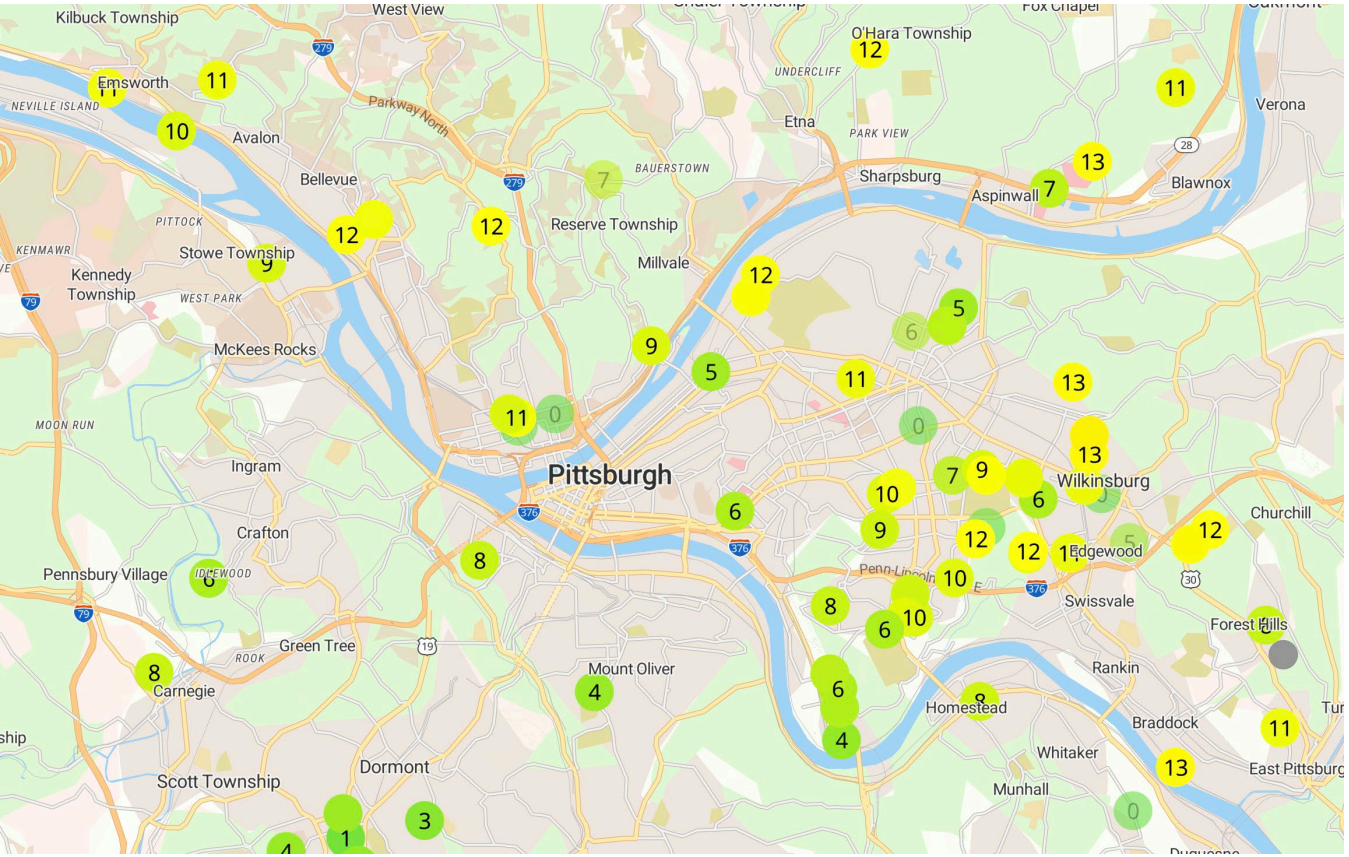
RAMBOLL Bright ideas. Sustainable change.

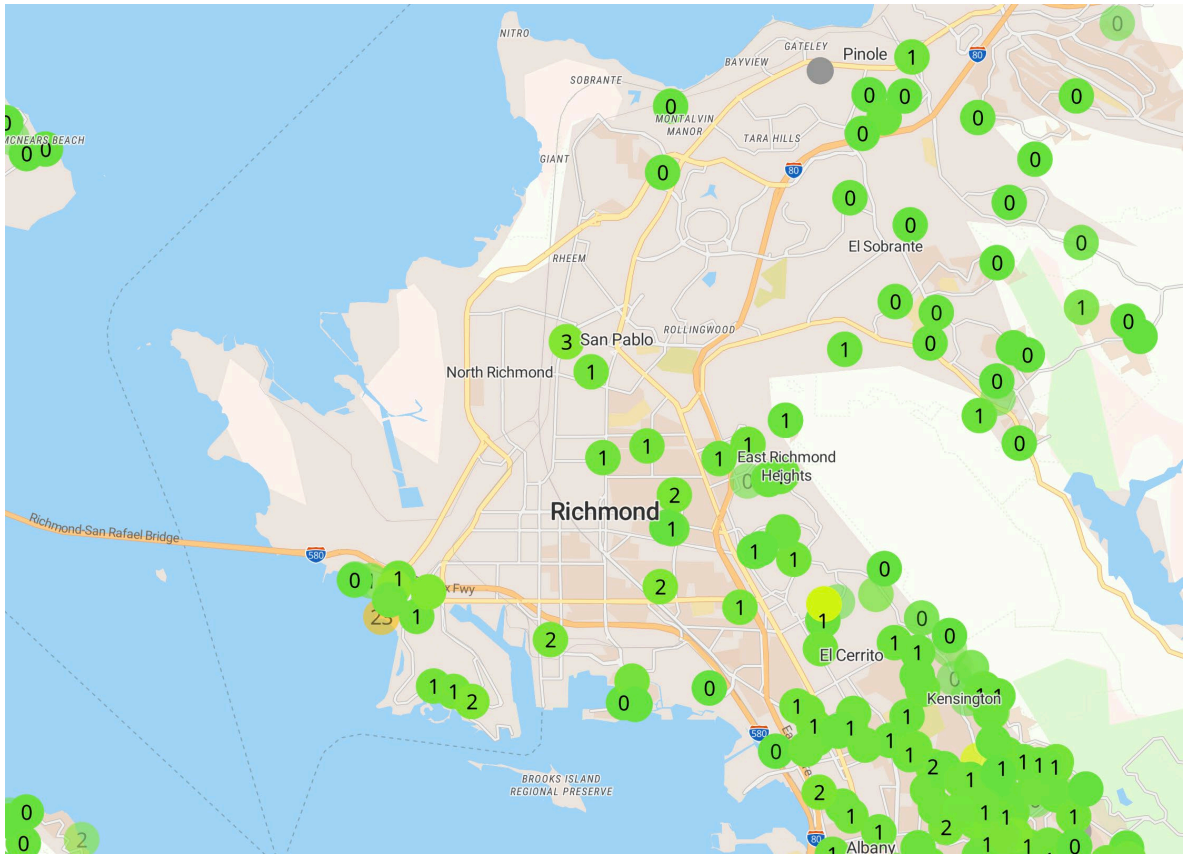
Shair

- Low-Cost Sensors are changing the conversion about air quality
- Public access to real-time air quality data with increased spatial and temporal resolution



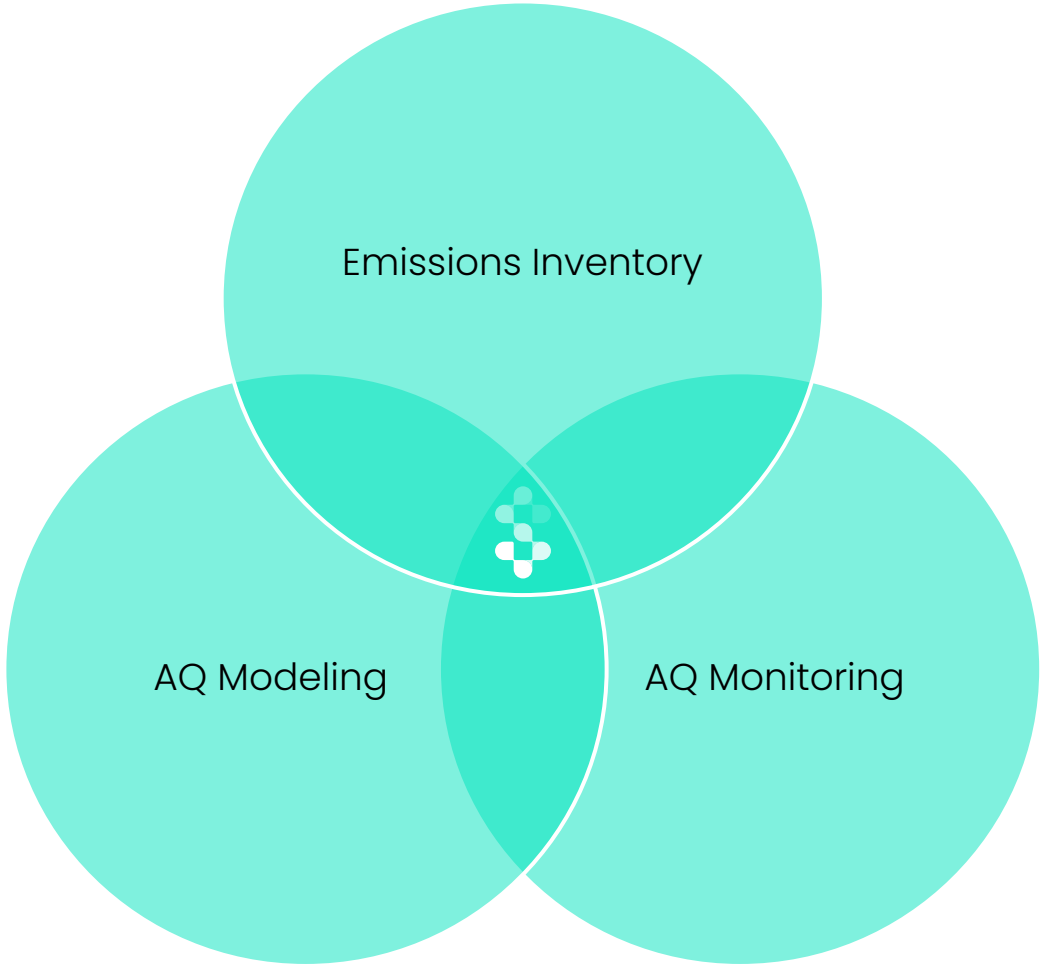
- Data gaps persist even with deployment of many low-cost sensors.
- Interpolation between monitoring sites fails to account for meteorology and chemistry away from the sensors.



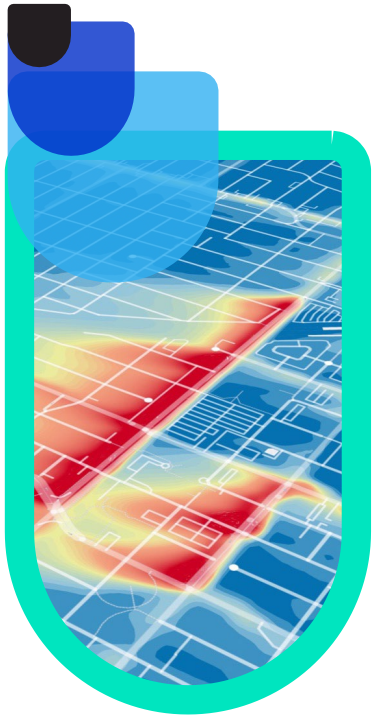


Shair: Real-Time Fusion of Air Quality Monitoring and Modeling

A new foundation from **combining** datasets



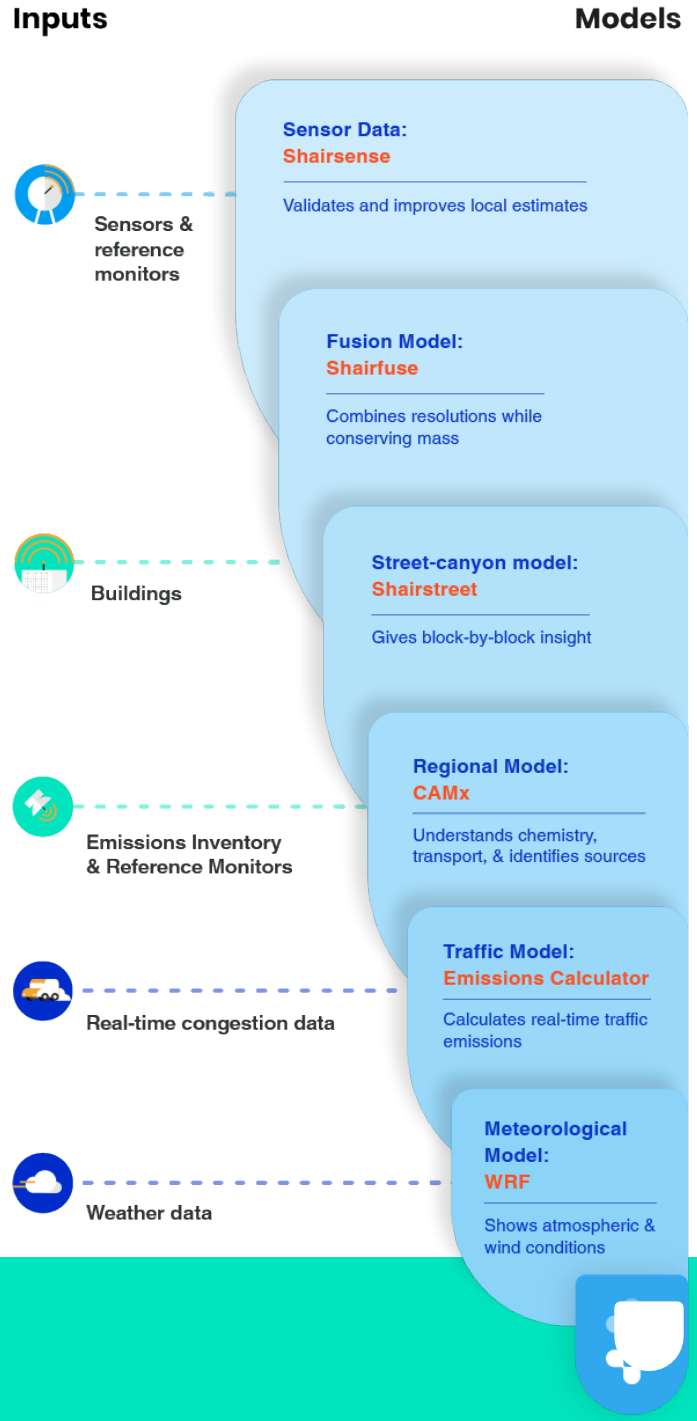
What **is** Shair?



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



Overview of Shair Model/Monitor Fusion

WRF
Meteorological Model

Overview of Shair Model/Monitor Fusion

1. WRF
   Meteorological Model

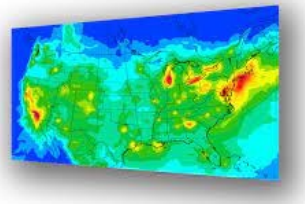
2. Online traffic and shipping module
   Calculates real-time emissions

Overview of Shair Model/Monitor Fusion

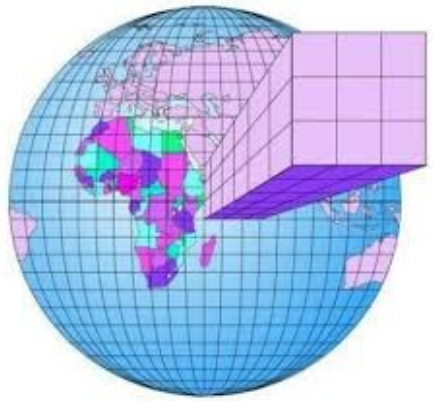
1. WRF
   Meteorological Model

2. Online traffic and shipping module
   Calculates real-time emissions

3. CAMx – Chemical Transport Model
   Simulates transport, diffusion and chemistry



CAMx
Ozone
Particulates
Toxics



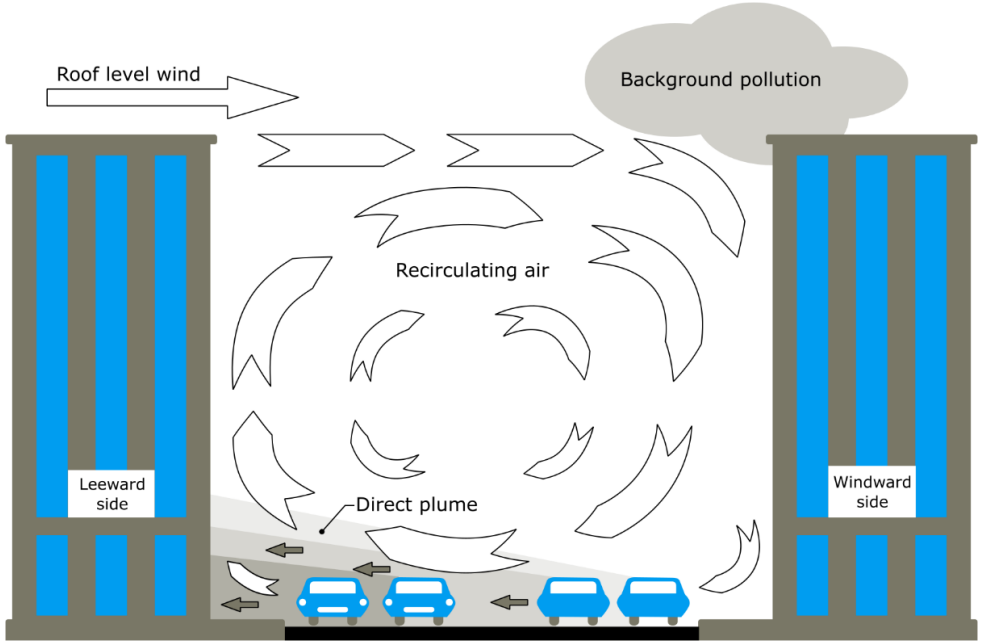
Overview of Shair Model/Monitor Fusion

1 WRF
Meteorological Model

2 Online traffic and shipping module
Calculates real-time emissions

3 CAMx – Chemical Transport Model
Simulates transport, diffusion and chemistry

4 Shairstreet
Street canyon model using building topography



Overview of Shair Model/Monitor Fusion

1. **WRF**
   Meteorological Model

2. **Online traffic and shipping module**
   Calculates real-time emissions

3. **CAMx – Chemical Transport Model**
   Simulates transport, diffusion and chemistry

4. **Shairstreet**
   Street canyon model using building topography

5. **Shairfuse**
   Combines CAMx and Shairstreet for high resolution air quality while conserving mass

Overview of Shair Model/Monitor Fusion

1. **WRF**
   Meteorological Model

2. **Online traffic and shipping module**
   Calculates real-time emissions

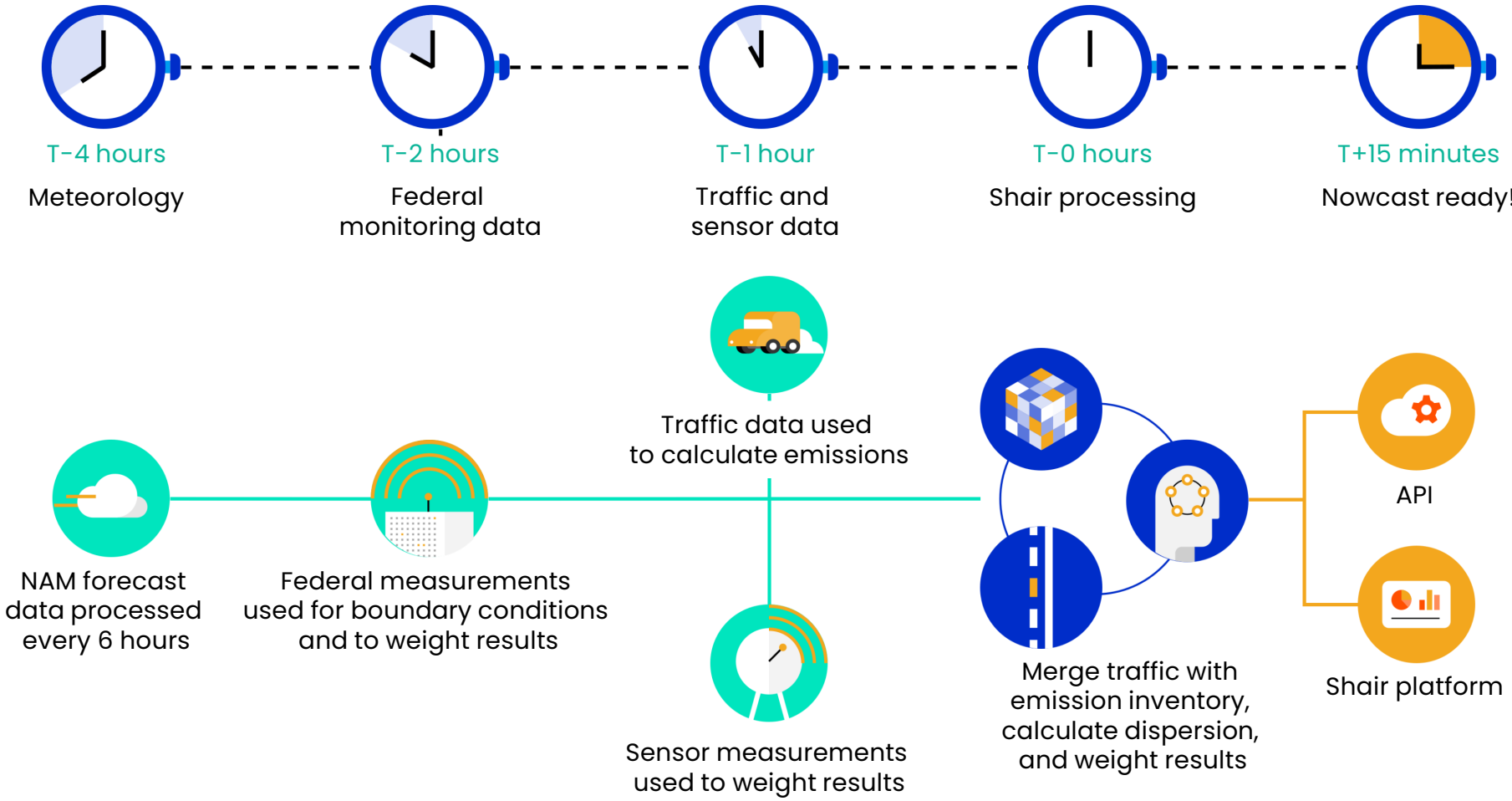
3. **CAMx – Chemical Transport Model**
   Simulates transport, diffusion and chemistry

4. **Shairstreet**
   Street canyon model using building topography

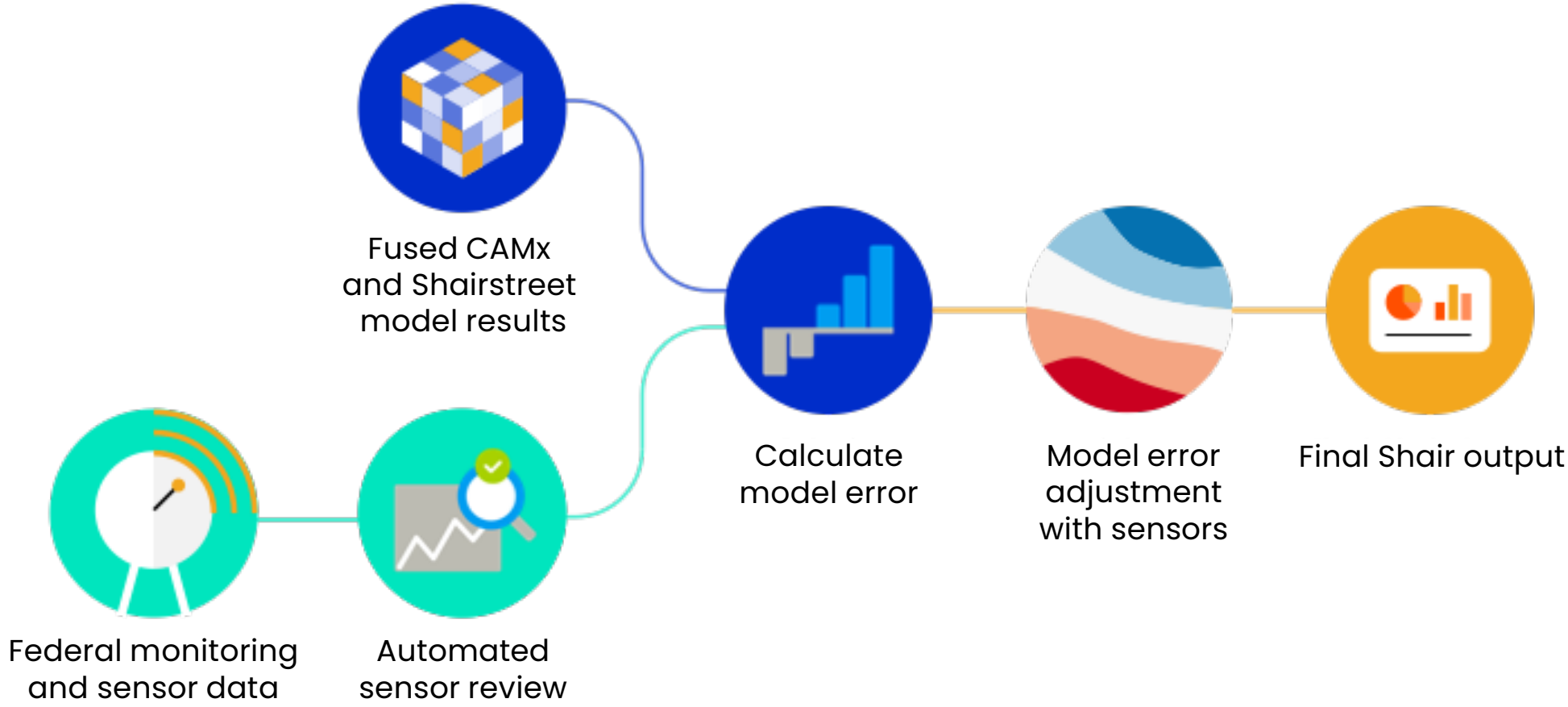
5. **Shairfuse**
   Combines CAMx and Shairstreet for high resolution air quality while conserving mass

6. **Shairsense**
   Fuses sensor and reference monitor data with modeling results

Nowcast Data Timing Summary

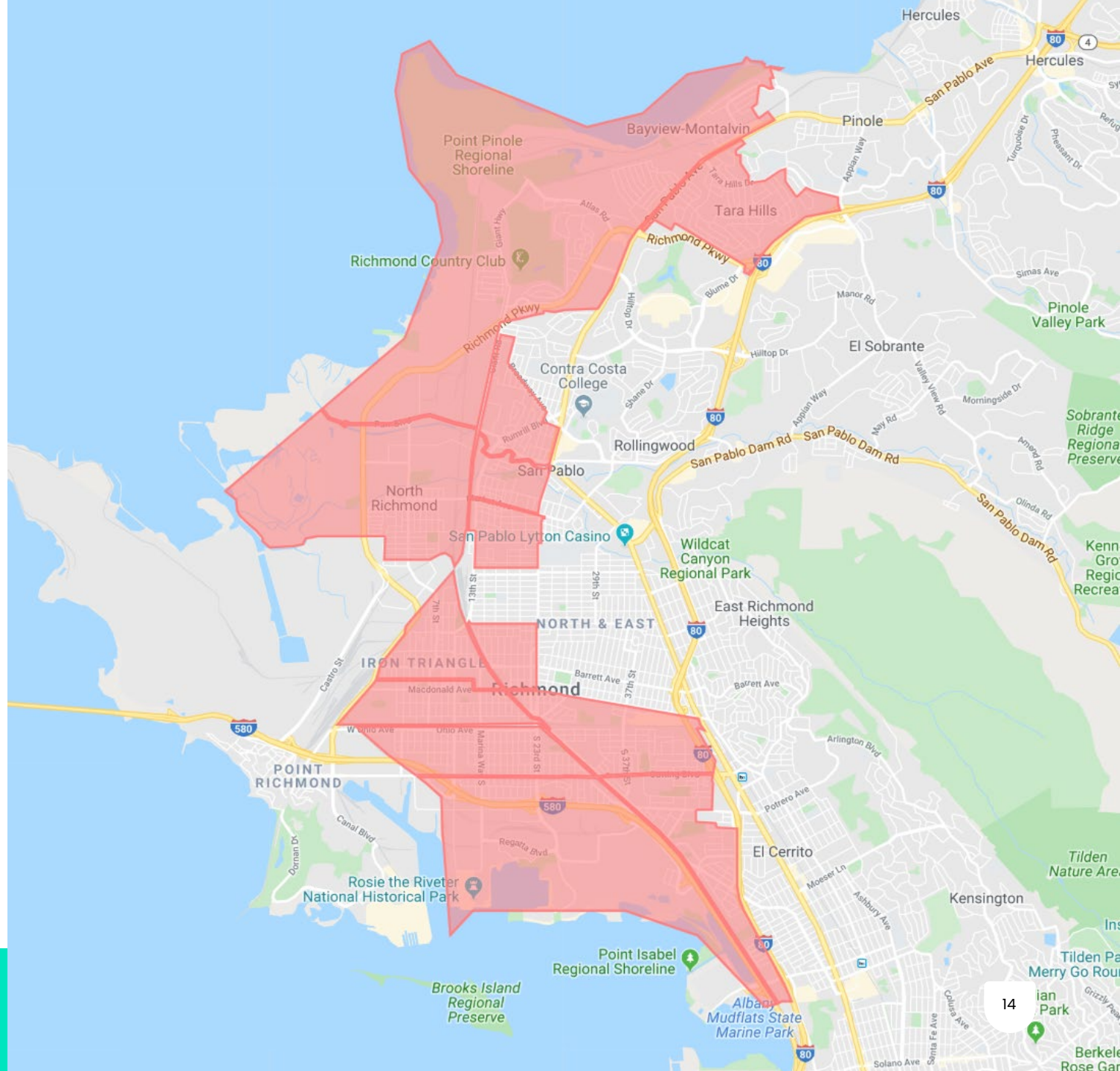


Shairsense Model Adjustment with Sensor Measurements



CA Assembly Bill 617

- Goal: Improve air quality in environmental justice communities through local, community-specific strategies
- Main elements:
  - Expedited schedule for implementation of best available retrofit control technology (BARCT) requirements
  - Deploy community air monitoring systems in certain identified communities
  - Implement plans to reduce emissions in those identified communities
- Apply Shair to Richmond, CA to provide high-resolution air quality
  - Major roadways (I-80, I-580)
  - Sources: Refineries; Industry; Shipping
  - Disadvantaged Communities



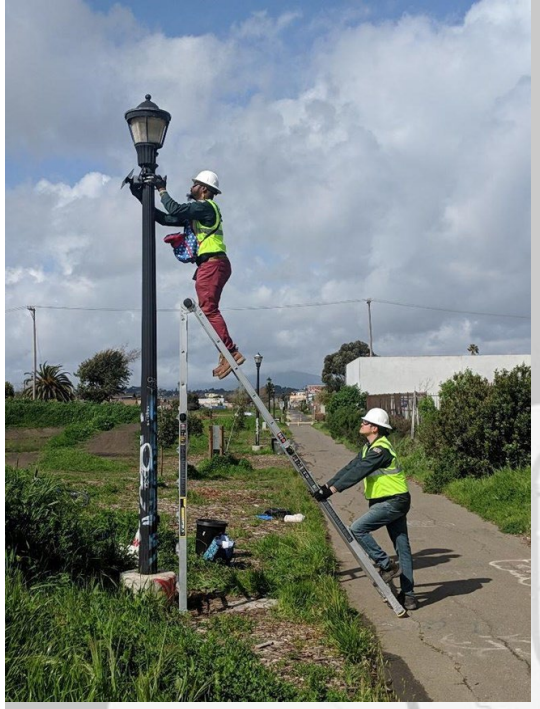
Some Questions We Sought to Answer

Sampling Background

AB617 Funded Project in Richmond, CA

Air Rangers I, II

- Expand sampling (50 Clarity sensors)
- Attribute hotspots to sources
- Share semi-real-time data with the public
- Facilitate healthy outdoor recreation
- Local work force development for disadvantaged youth



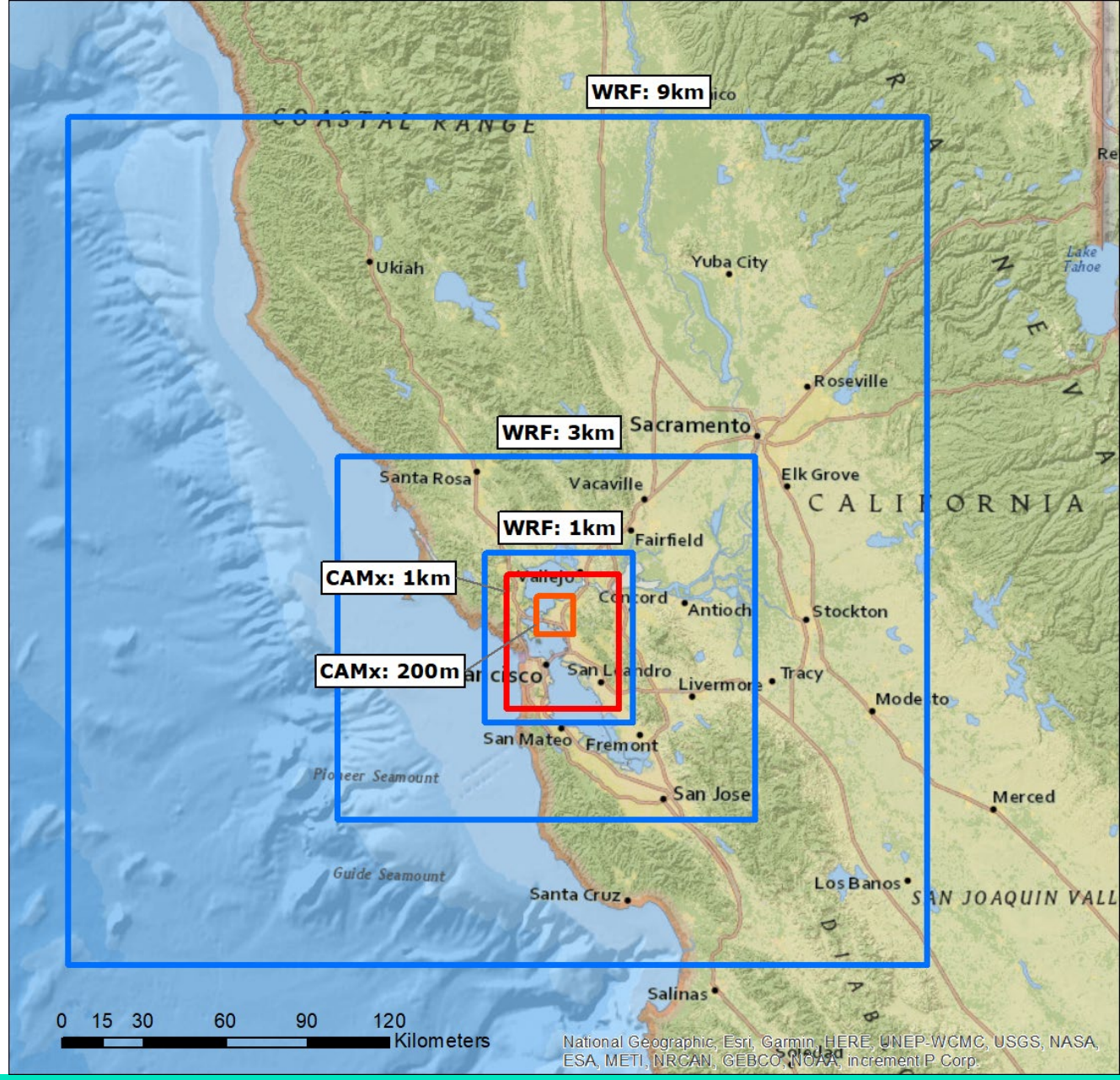
Shair Configuration in Richmond

Meteorology

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

CAMx

- 1-km and 200-m grids
- Fast chemical scheme for O_3-NO-NO_2
- Wet and dry deposition with ZHANG03 model
- Tag emissions by source category for source apportionment
- Latest emissions combined with previous hour dispersion results



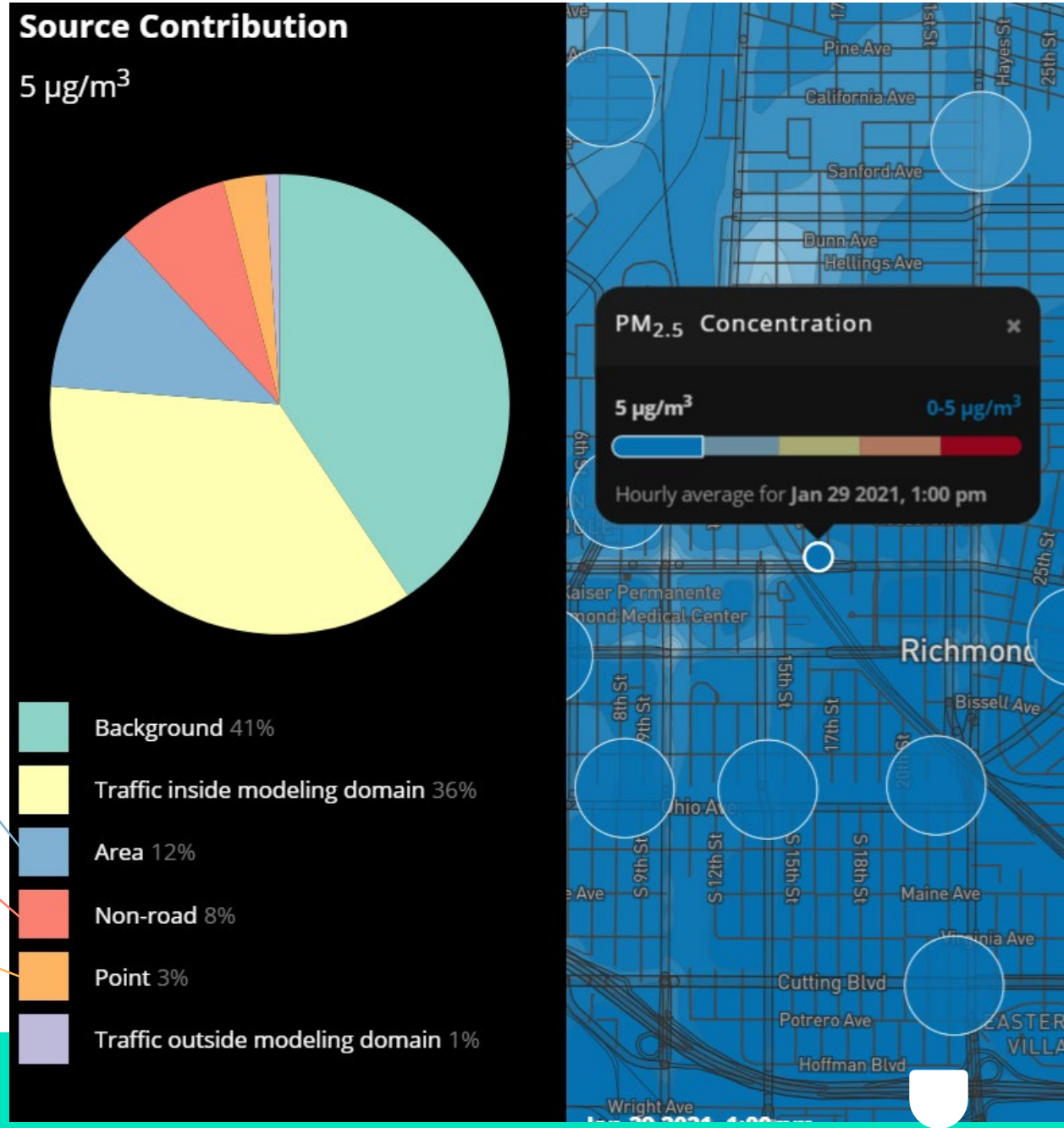
Where is Pollution coming from?

Pie chart → Local source contributions to $PM_{2.5}$ (appear upon clicking any point)

Area sources:
- Wood burning
- Fugitive dust
- Restaurants

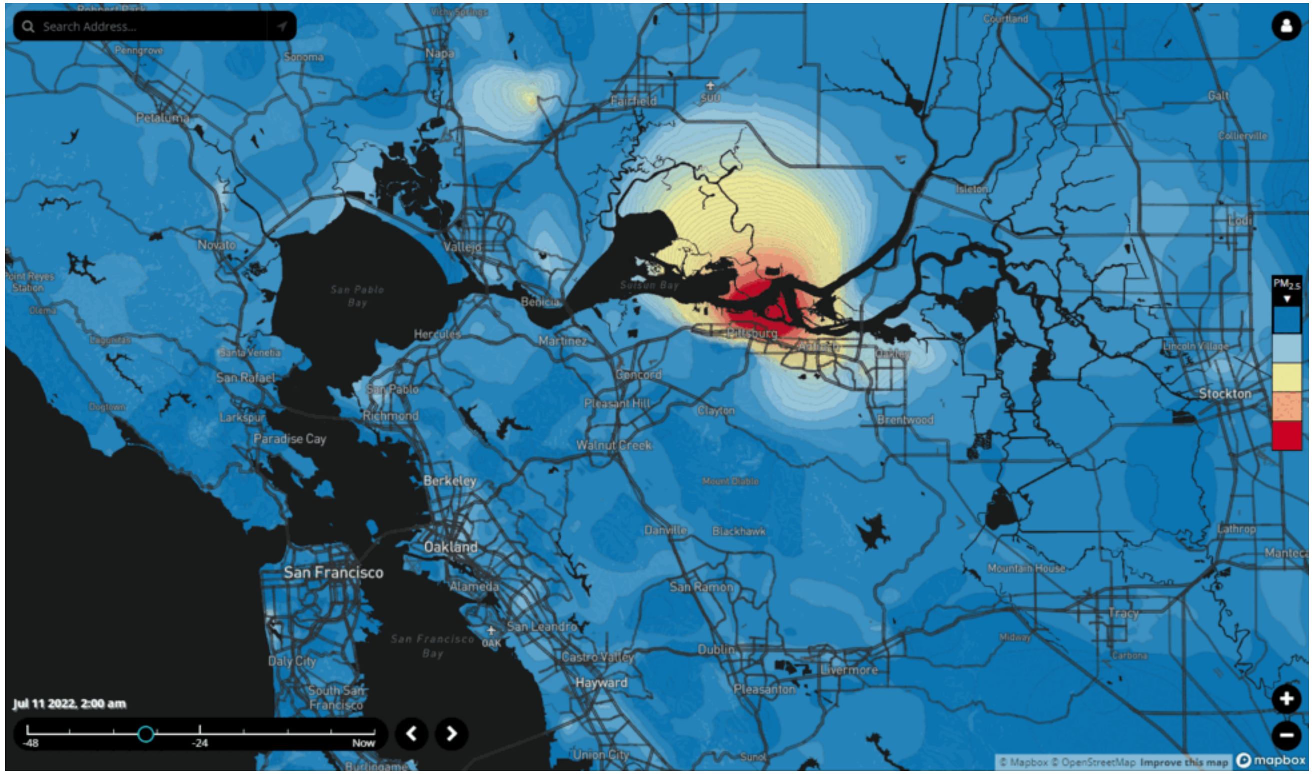
Non-road sources:
- Shipping
- Railroads
- Non-traffic engines

Point sources:
- Industrial stacks

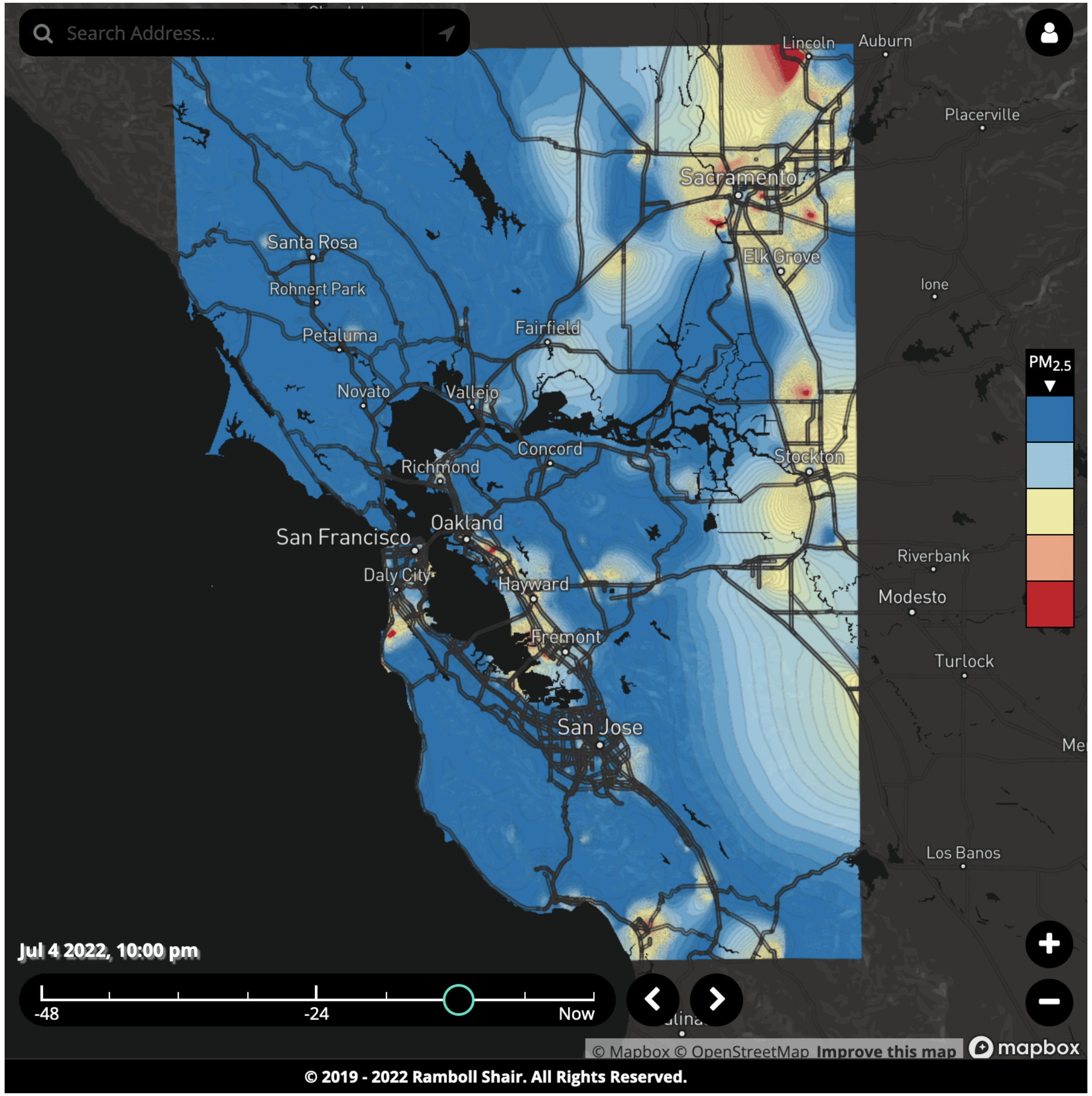


Shair

Shair Shows Spatial and Temporal Variation



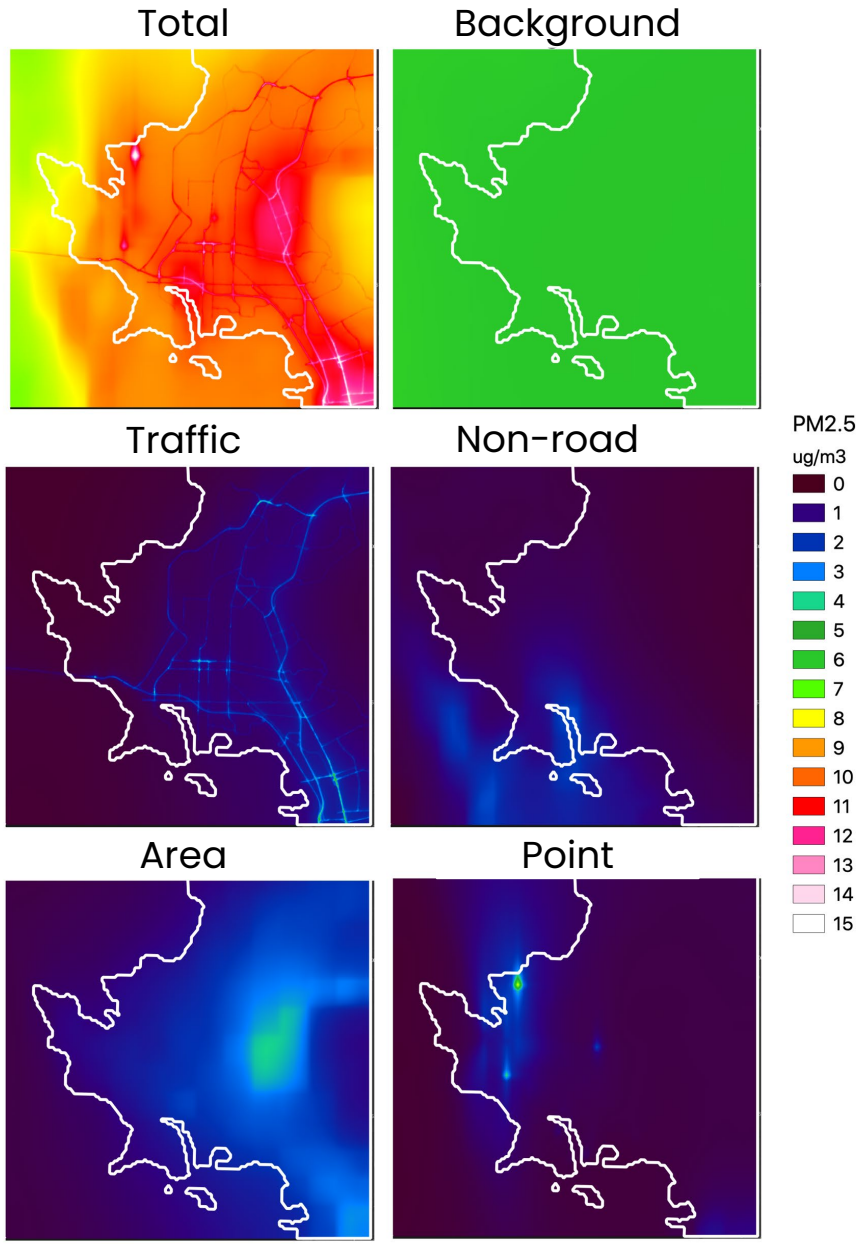
Pittsburg Marsh Fire July 11, 2022



July 4th, 2022

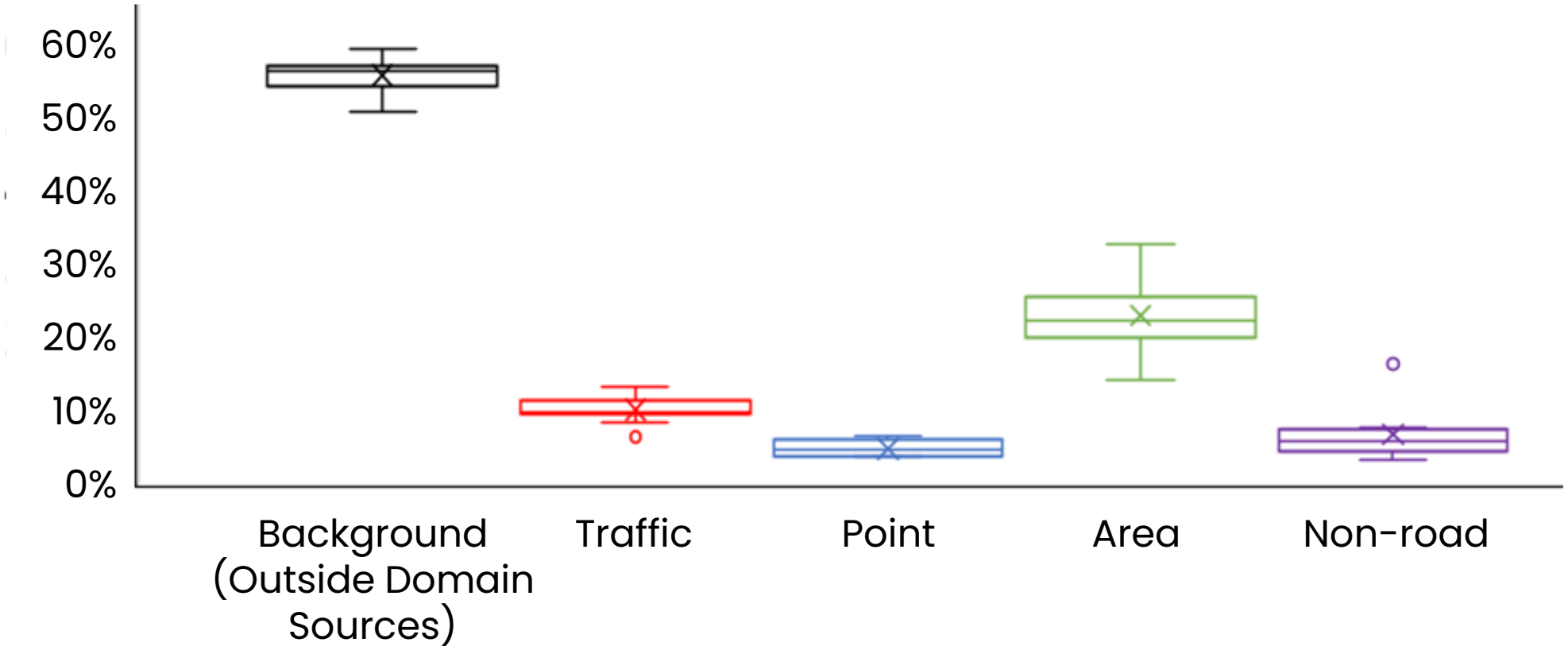
Annual Average $PM_{2.5}$ Source contribution

1. Background (outside domain sources) concentration of 6 [μg m^{-3}] consistent with BAAQMD
2. Traffic is ~2-3 [μg m^{-3}] on average.
3. Non-road contribution is around 3 [μg m^{-3}] mainly originating from ports
4. Area sources are mainly residential wood and natural gas burning.
5. Point source concentrations are elevated near the refinery and industrial areas



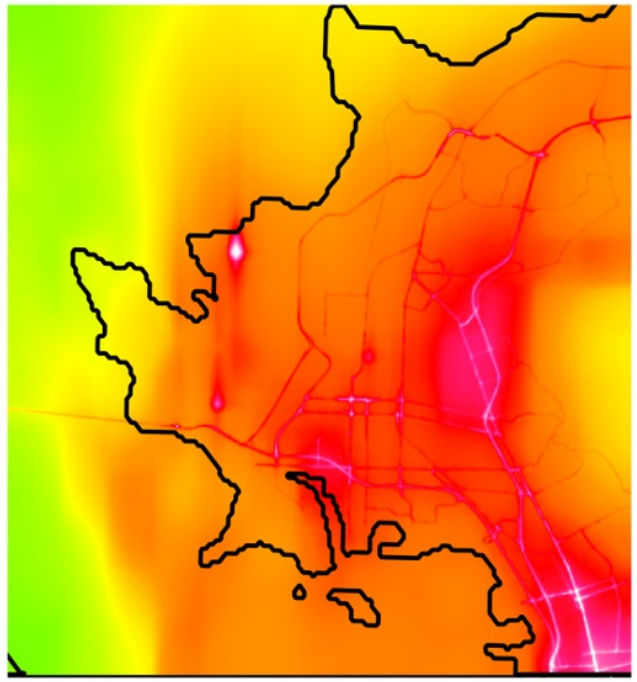
Shair Shows Source Contribution

Area sources are the biggest local contributor to $PM_{2.5}$ in Richmond in 2020

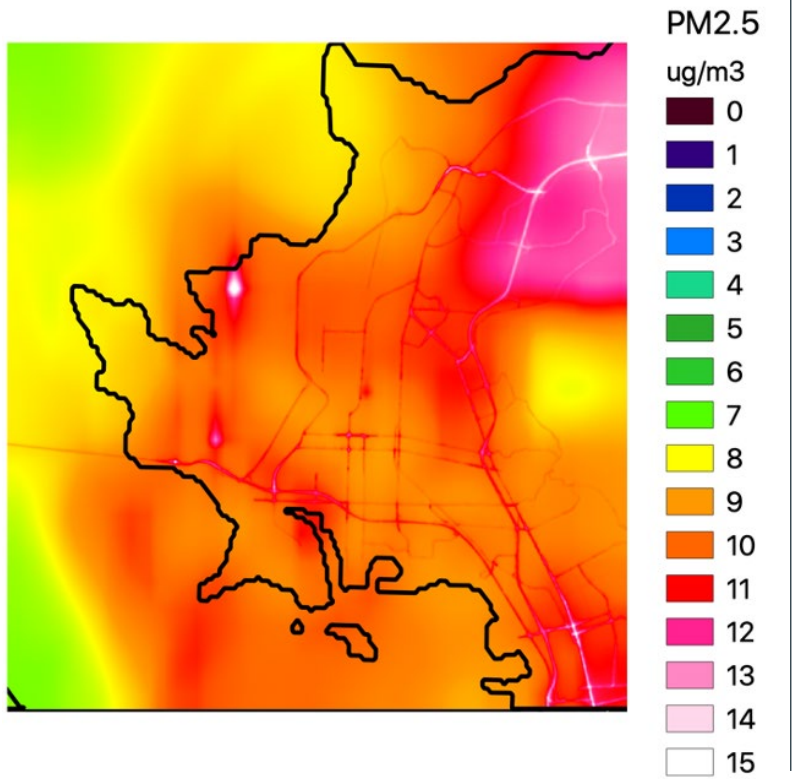


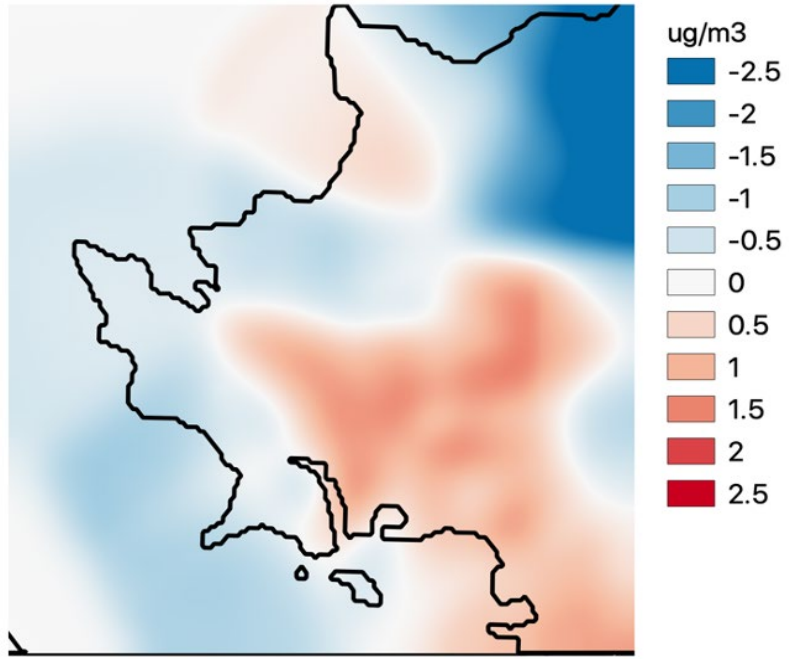
Shair is able to show model over/underprediction over a domain

Model predicted



Shair adjusted





Conclusion

1. Shair is modular, efficient, and scalable. It combines state-of-the-art modeling with the latest software engineering tools.

2. High density of sensors empowers Shair to address biases in emission inventories and modeling artifacts

3. Shair provided actionable insights to guide emission inventory review and improvement

Thanks!

aakherati@ramboll.com
rzhang@ramboll.com
slibicki@ramboll.com

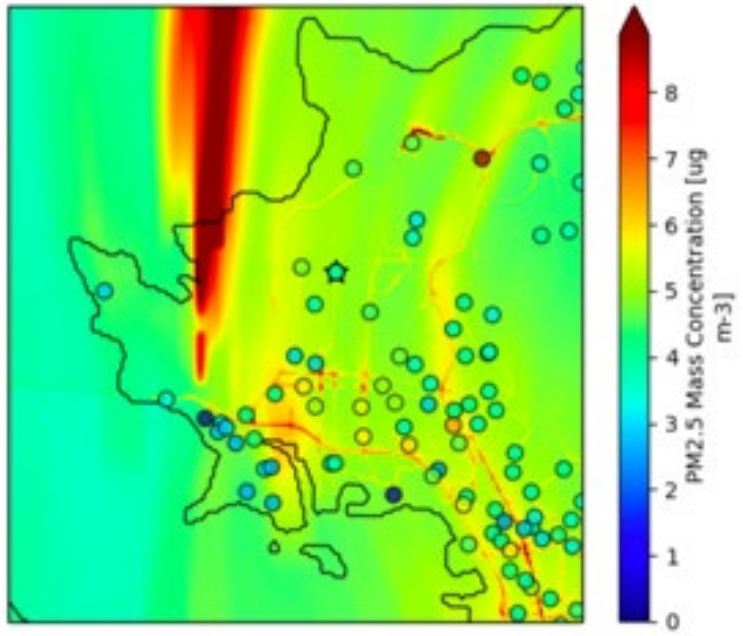
https://app.ramboll-shair.com/

@ramboll_shair

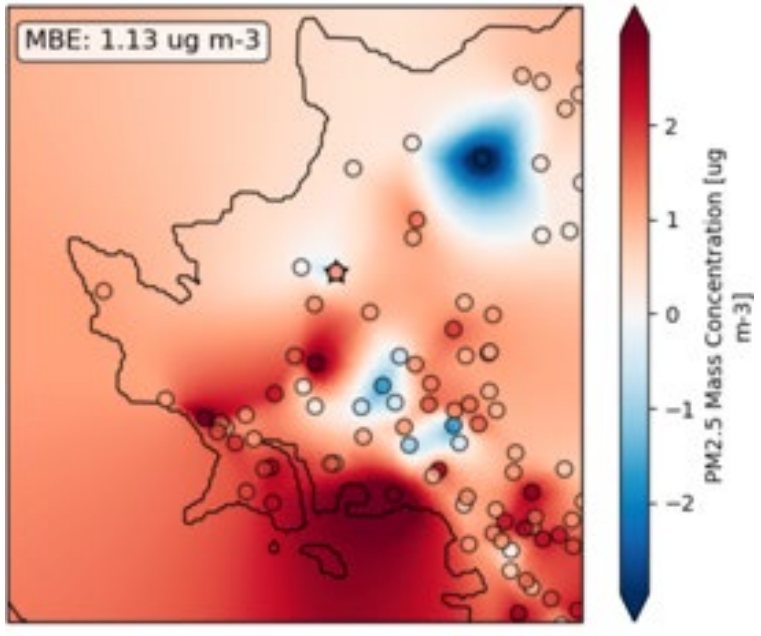
Extra slides

Voronoi nearest neighbour used for the model-measurement comparisons

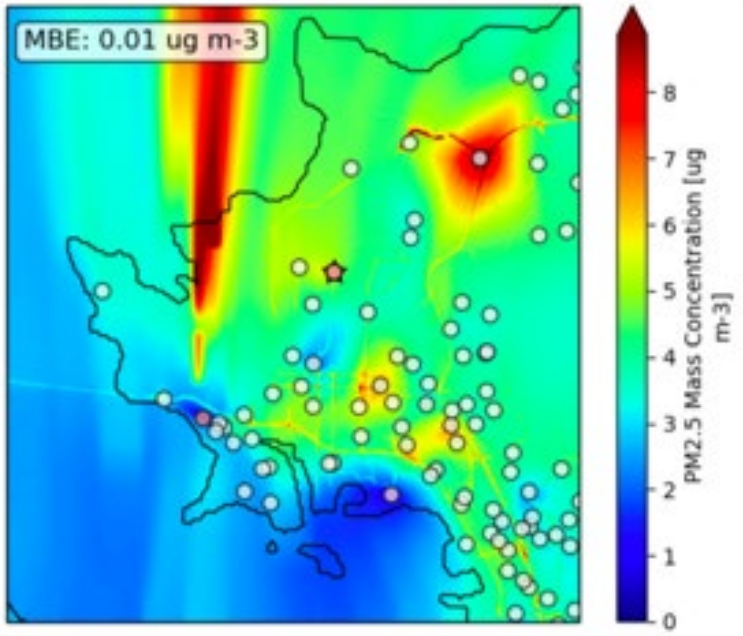
Unadjusted model



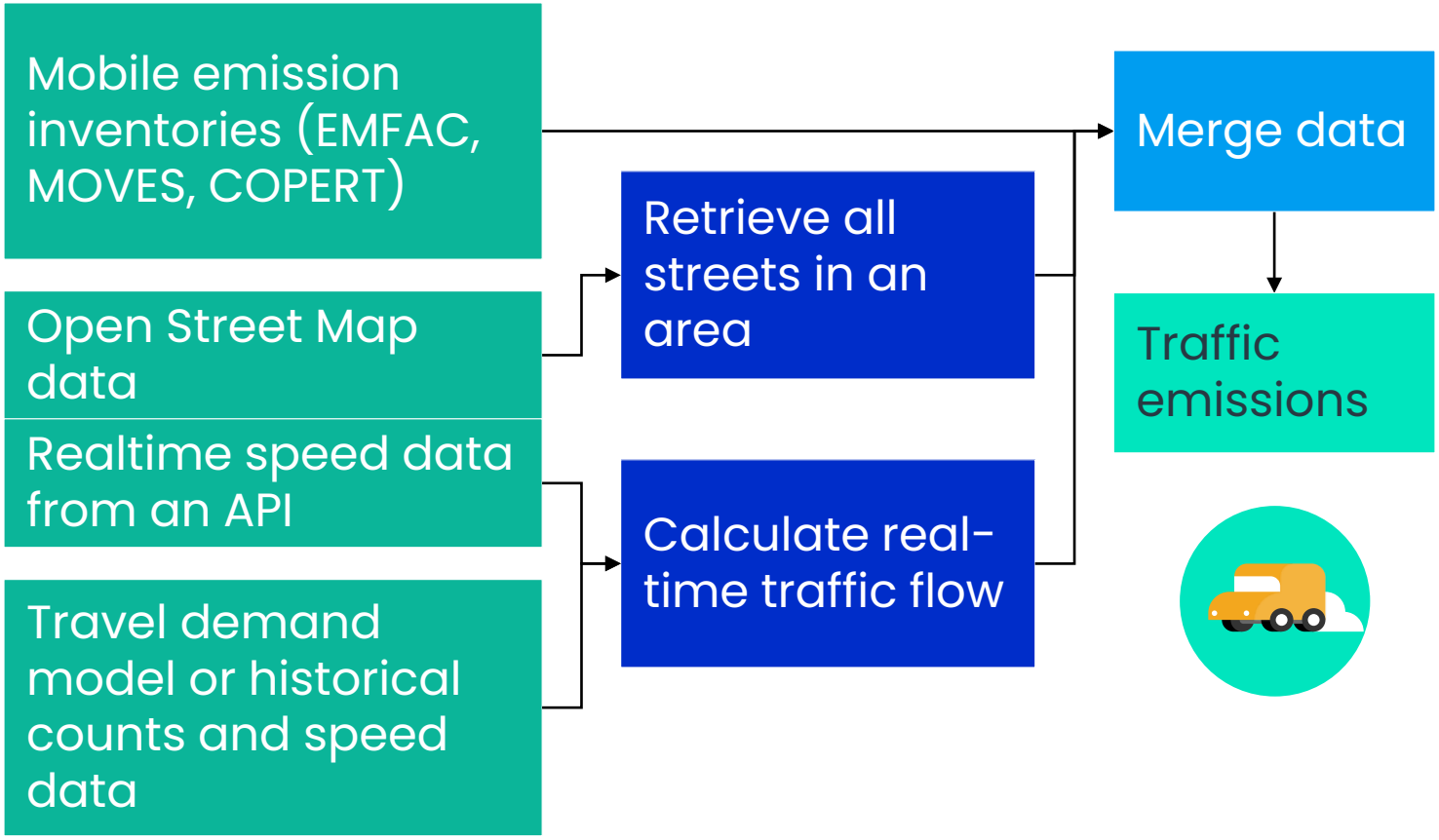
Model error (interpolated)

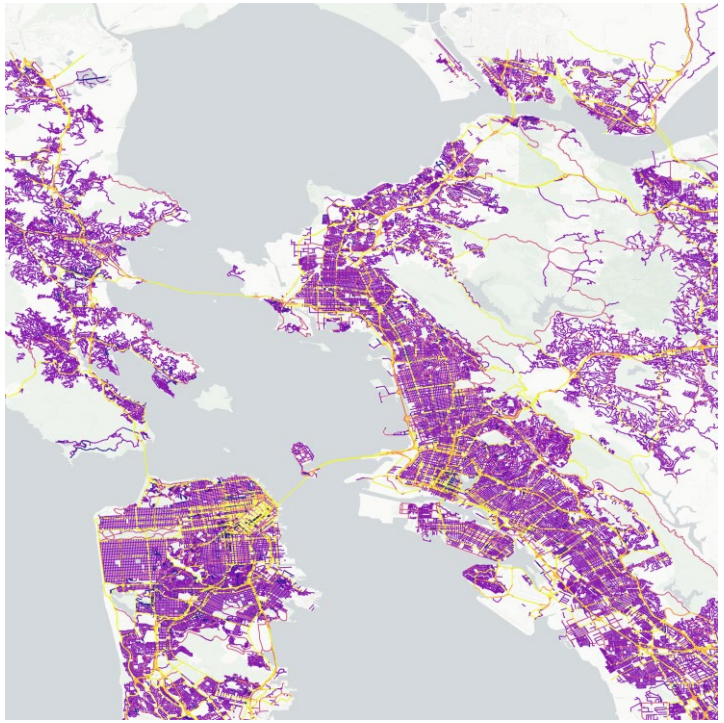


Blended model + observations



Real-time Traffic Emissions





358,269 Modeled Road Links in the Bay Area

Future work

01

Perform more time-resolved analysis to investigate source specific trends and modelling performance during the day and over seasons

02

Deploy more sensors near under-sampled areas (e.g., Northeast Richmond) for more powerful emission inventory evaluation

03

Implement real-time ship emissions using vessel identification and position data

04

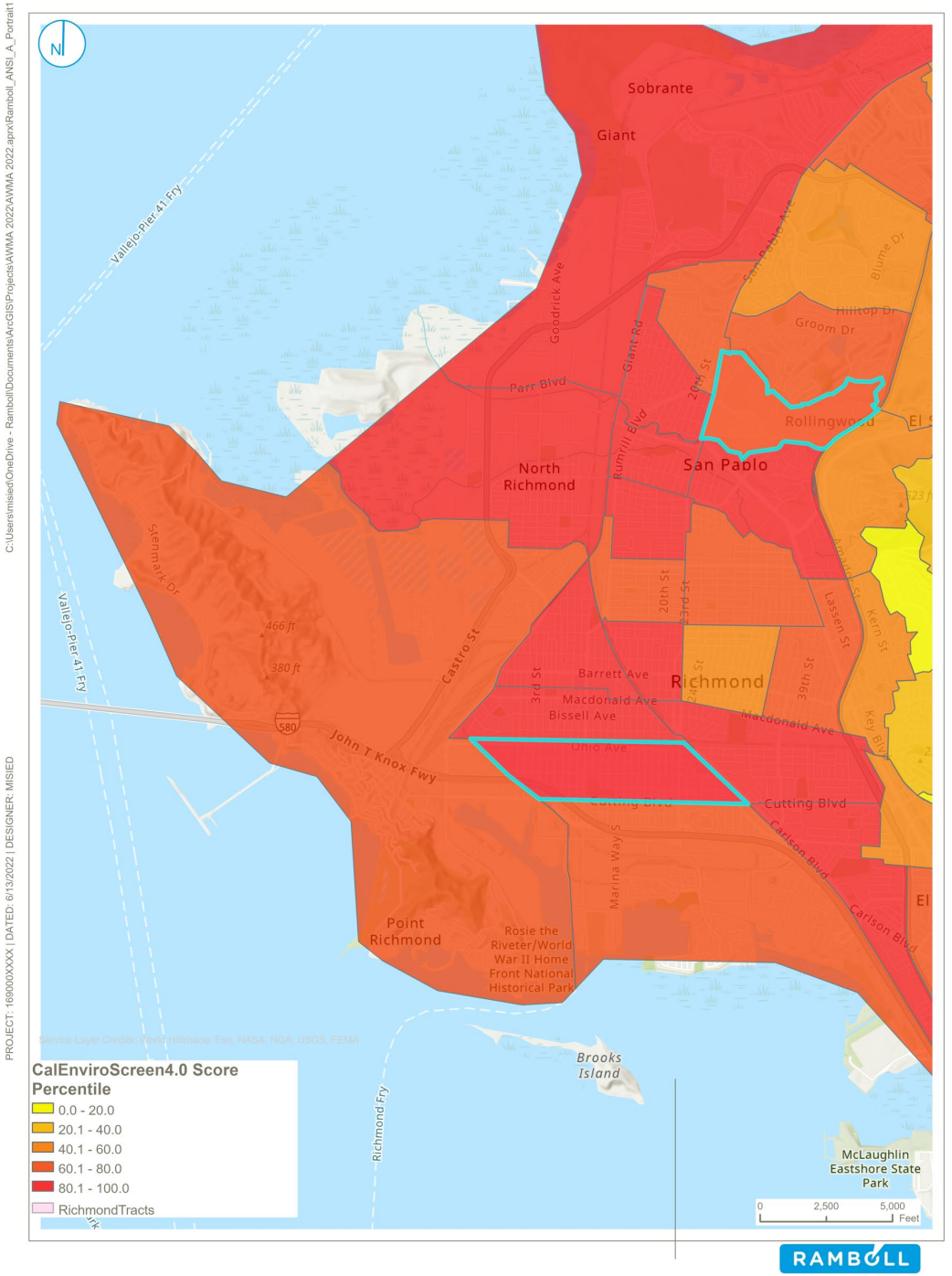
Review emission inventory methods for area and mobile sources in locations where model biases are apparent

05

Multi-pollutant analysis with more accurate measurements of gaseous pollutants would help to distinguish the source patterns more clearly

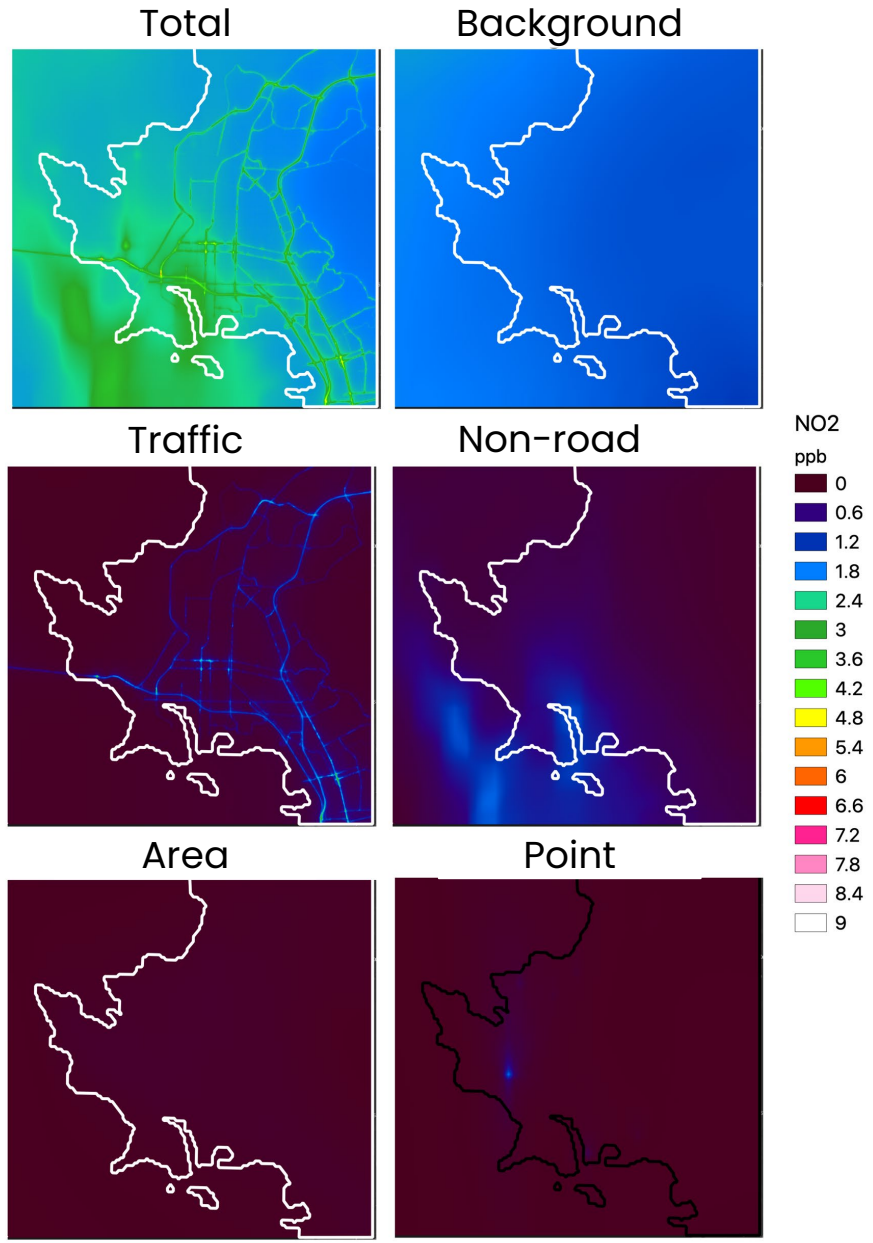
Selected Census Tracts for EJ

- CalEnviroScreen 4.0 scores about the 80th percentile
  - A screening tool to identify communities most burdened by pollution
  - Higher score indicates more vulnerability to pollutants
- Sensitive Land Uses – Residential and School Parcels
  - Selected census tract with greatest density of residential and school land uses within the Richmond Community

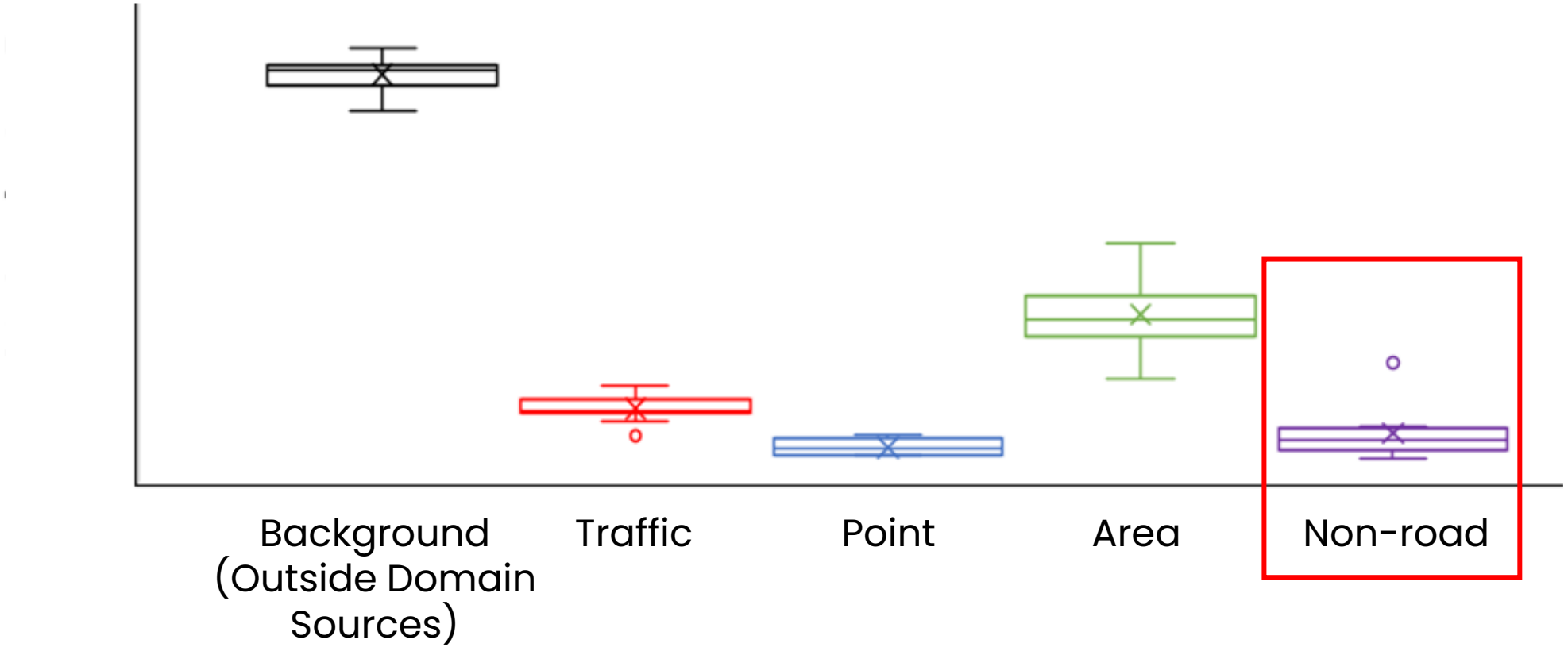


Annual Average NO_2 Source contribution

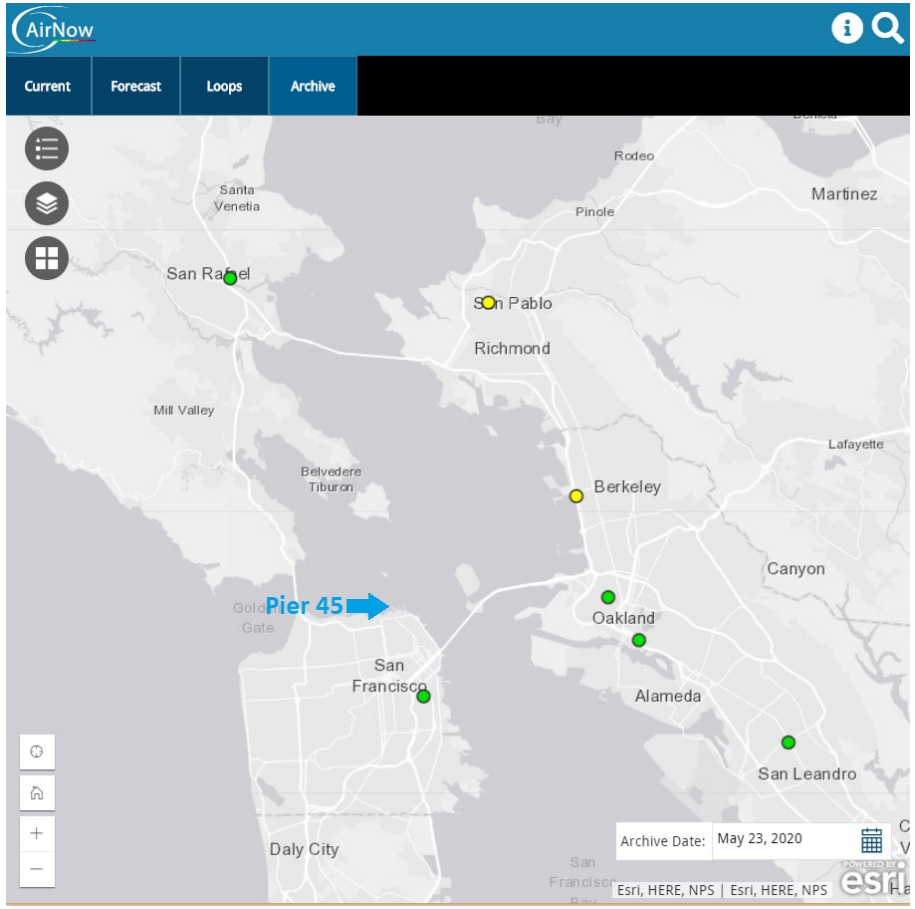
1. Dominated by traffic and non-road sources.
2. No contribution from area source.

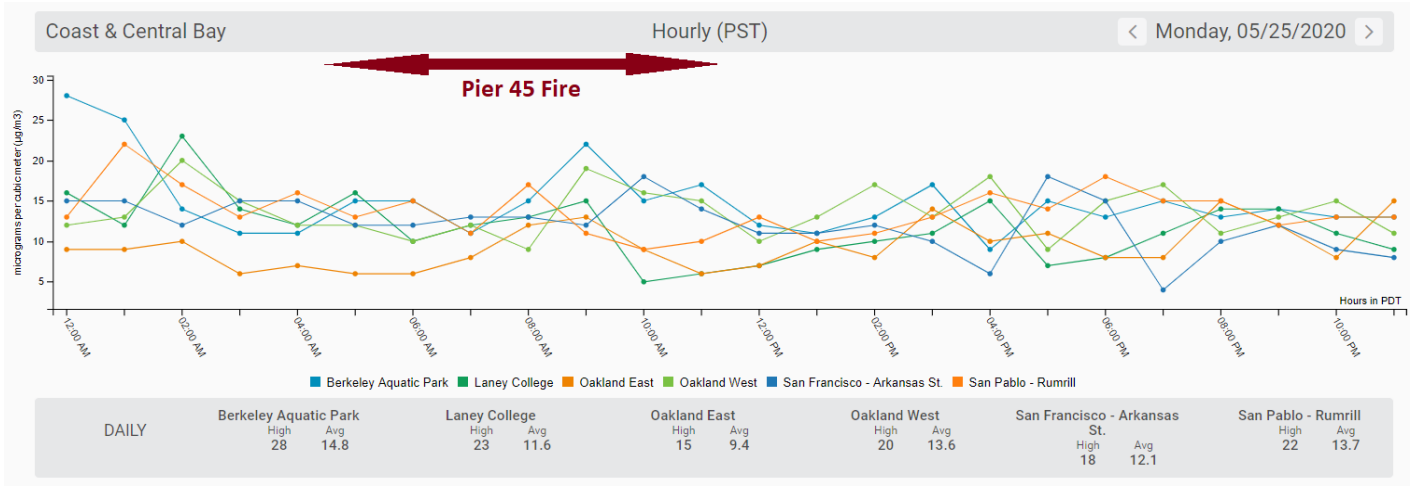


5 sensors located near port communities had 16-17% of estimated contributions from non-road sources to $PM_{2.5}$ similar to area source contribution

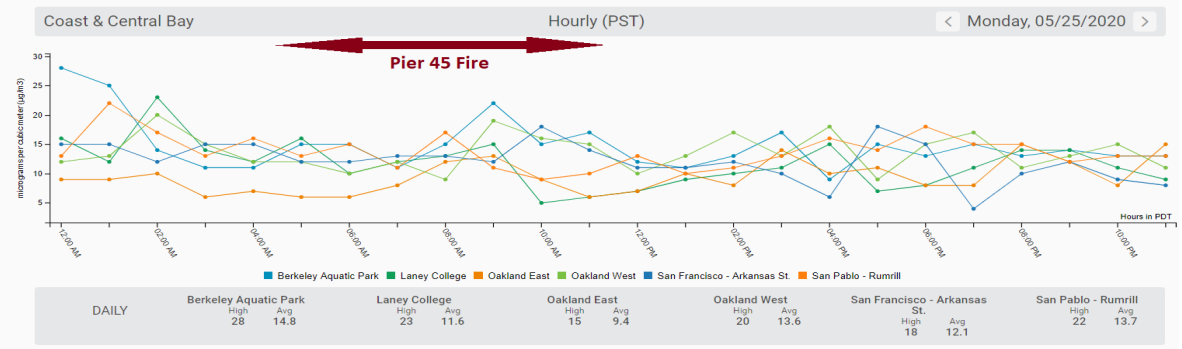


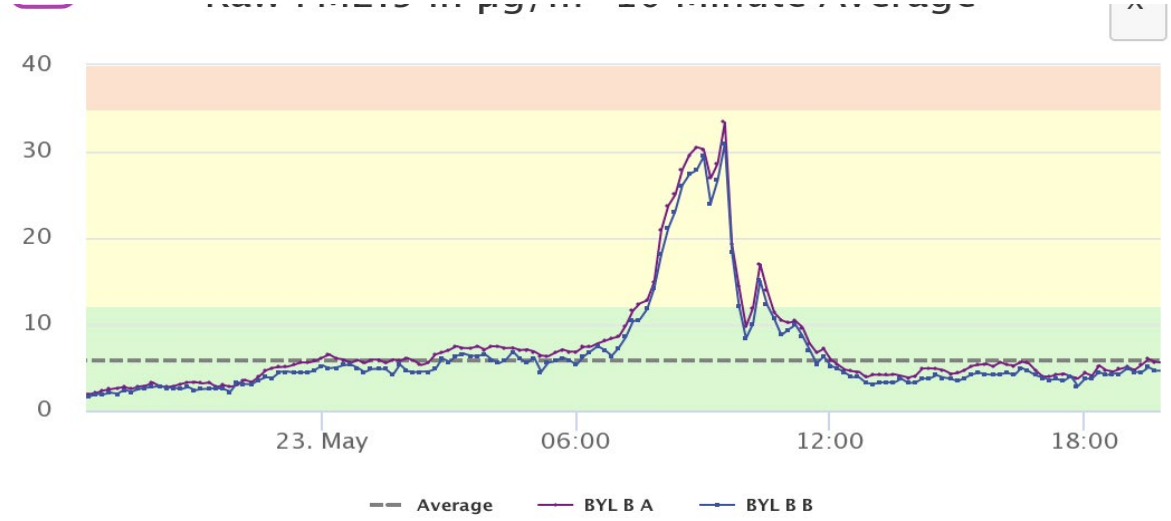
Quantifying localized impacts from fire events

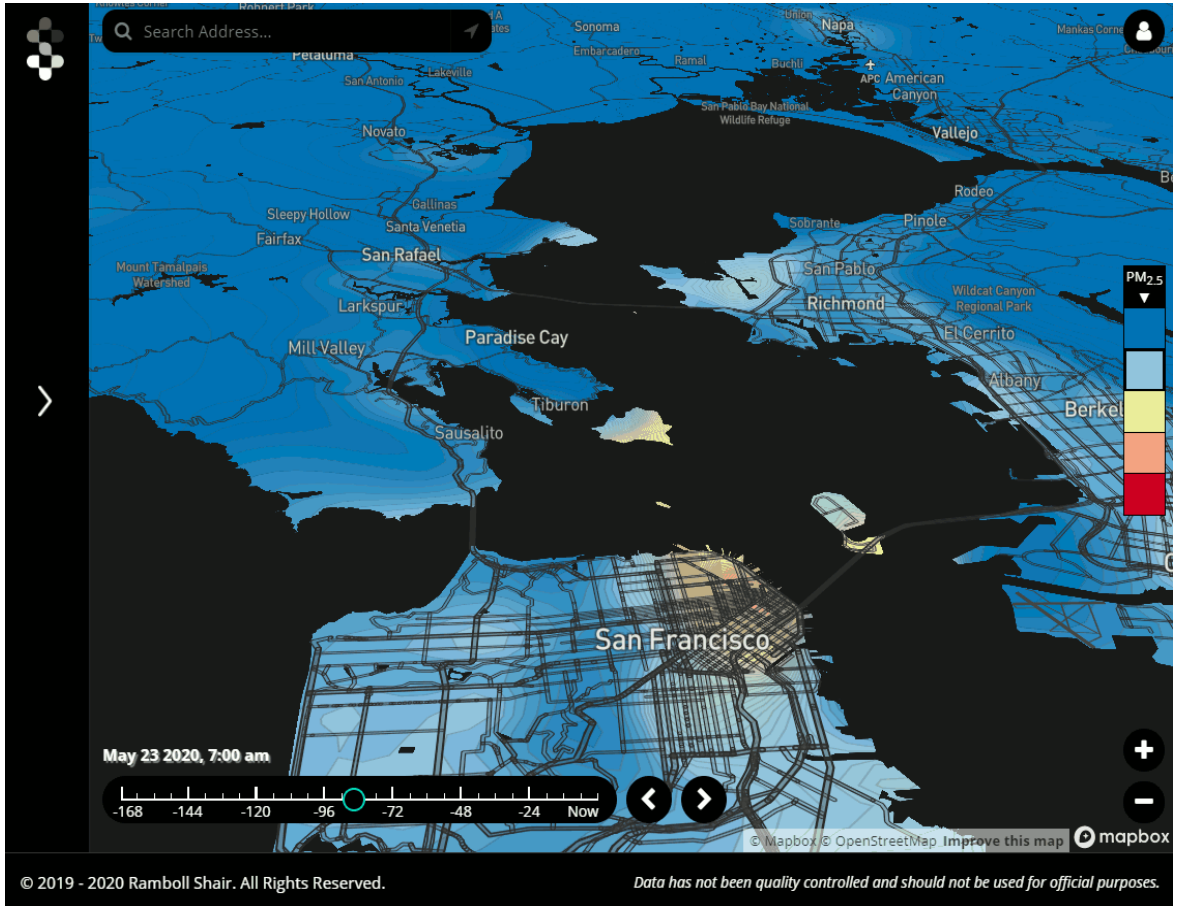


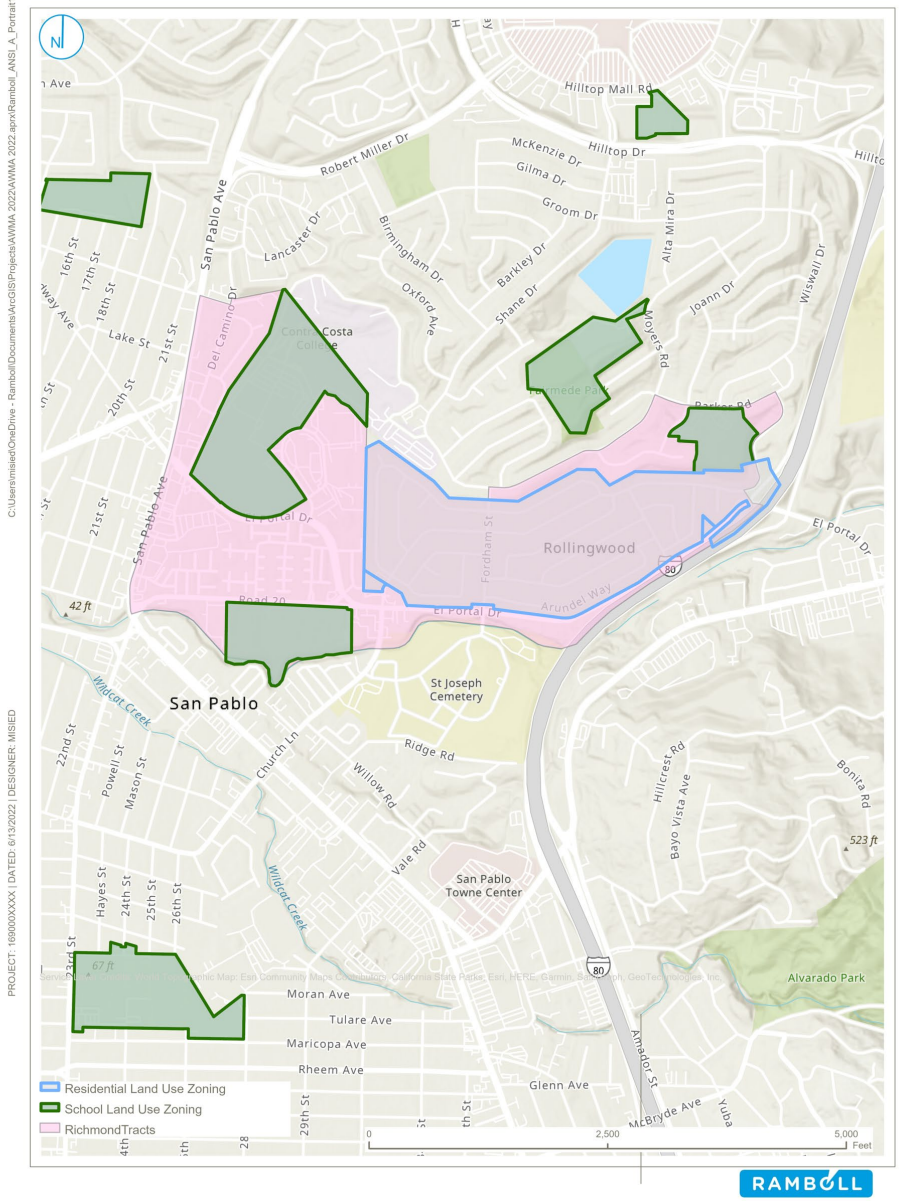


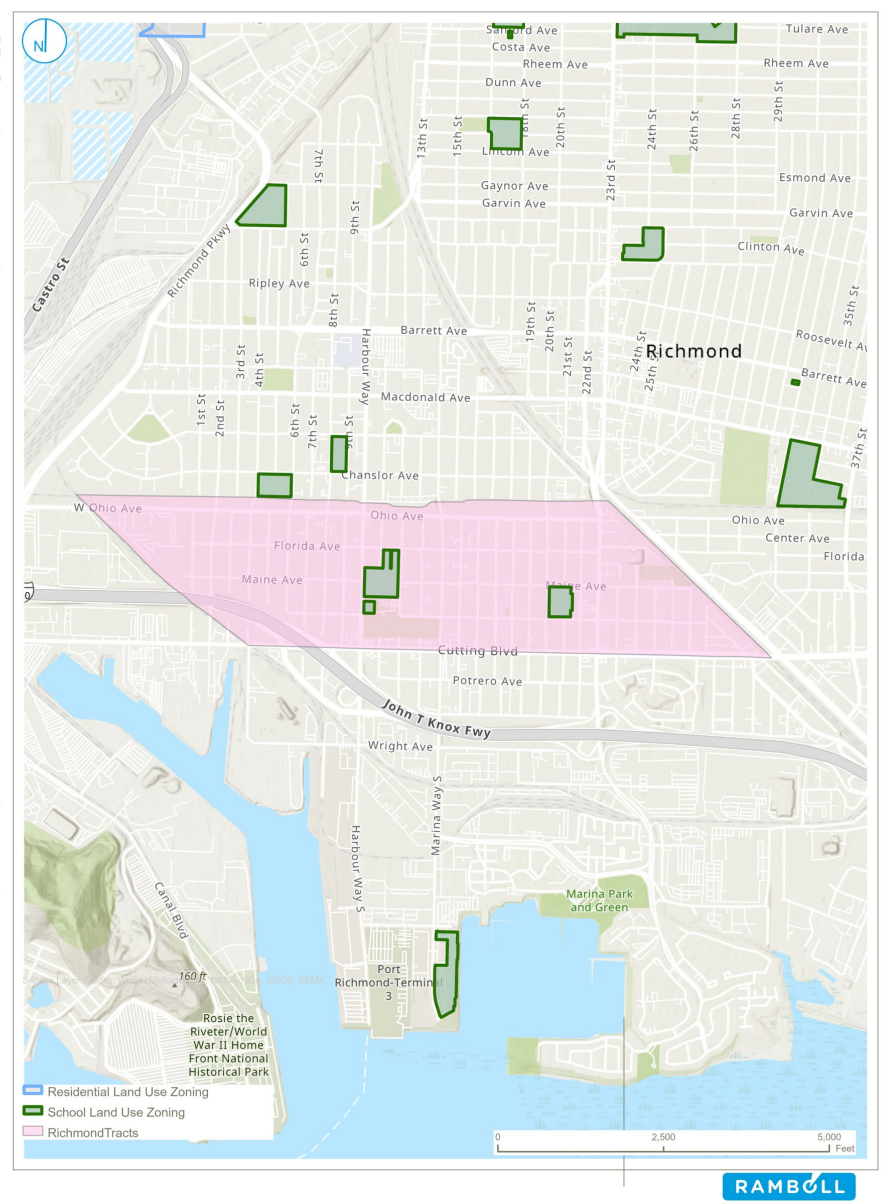
Quantifying localized impacts from fire events





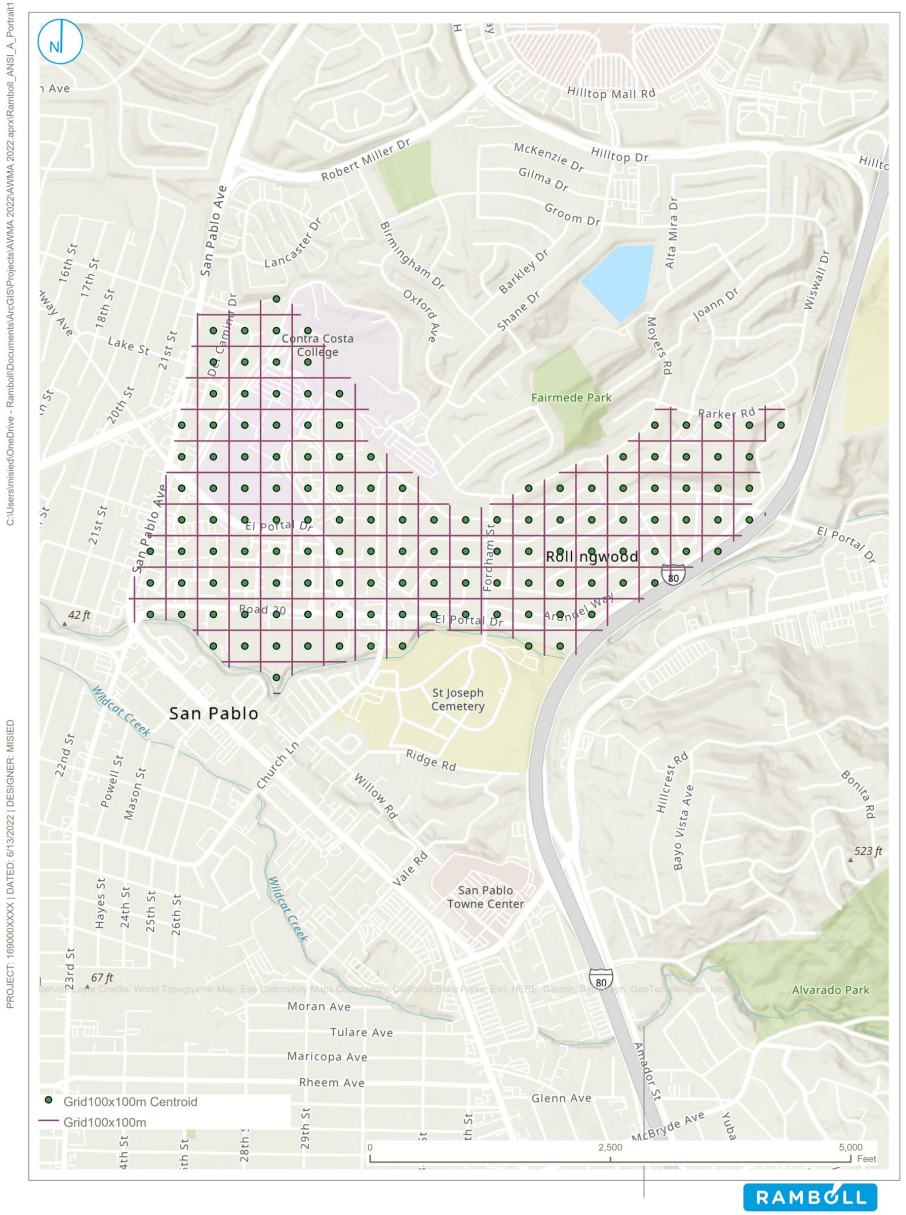


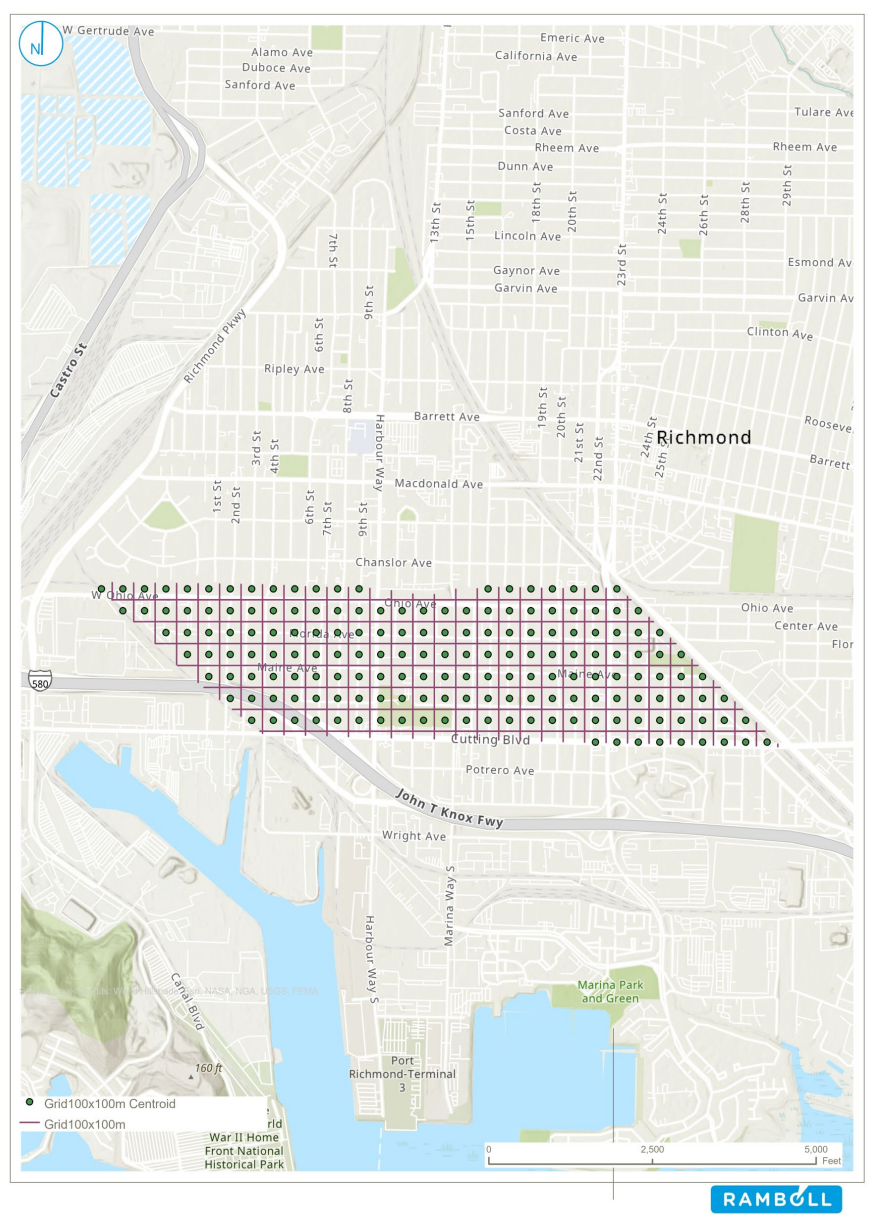

C:\Users\misied\OneDrive - Ramboll\Documents\ArcGIS\Projects\AWMA 2022\AWMA 2022.aprx\Ramboll_ANSI_A_Portrait1
PROJECT: 1690000XXXX | DATED: 6/13/2022 | DESIGNER: MISIED
San Pablo
Rollingwood
St Joseph Cemetery
San Pablo Towne Center
Alvarado Park
Hilltop Mall Rd
Hilltop Dr
Robert Miller Dr
McKenzie Dr
Gilma Dr
Groom Dr
Lancaster Dr
Birmingham Dr
Oxford Ave
Barkley Dr
Shane Dr
Alta Mira Dr
Joann Dr
Wiswall Dr
Moyers Rd
San Pablo Ave
Del Camino Dr
Lake St
Fordham St
Arundel Way
El Portal Dr
Church Ln
Ridge Rd
Willow Rd
Vale Rd
Wildcat Creek
Hillcrest Rd
Bayo Vista Ave
Bonita Rd
Moran Ave
Tulare Ave
Maricopa Ave
Rheem Ave
Glenn Ave
McBryde Ave
Amador St
42 ft
523 ft
67 ft
80
0
2,500
5,000
Feet
Residential Land Use Zoning
School Land Use Zoning
RichmondTracts
RAMBOLL


C:\Users\misied\OneDrive - Ramboll\Documents\ArcGIS\Projects\AWMA 2022\AWMA 2022.aprx\Ramboll_ANSI_A_Portrait1
PROJECT: 1690000XXXX | DATED: 6/13/2022 | DESIGNER: MISIED
Richmond
Castro St
Richmond Pkwy
Ripley Ave
Barrett Ave
Macdonald Ave
Chanslor Ave
W Ohio Ave
Ohio Ave
Florida Ave
Maine Ave
Cutting Blvd
Potrero Ave
John T Knox Fwy
Wright Ave
Harbour Way S
Marina Way S
Canal Blvd
Marina Park and Green
Port Richmond-Terminal 3
Rosie the Riveter/World War II Home Front National Historical Park
Tulare Ave
Rheem Ave
Dunn Ave
Costa Ave
Lincoln Ave
Gaynor Ave
Garvin Ave
Esmond Ave
Clinton Ave
Roosevelt Ave
Center Ave
160 ft
0
2,500
5,000
Feet
Residential Land Use Zoning
School Land Use Zoning
RichmondTracts
RAMBOLL

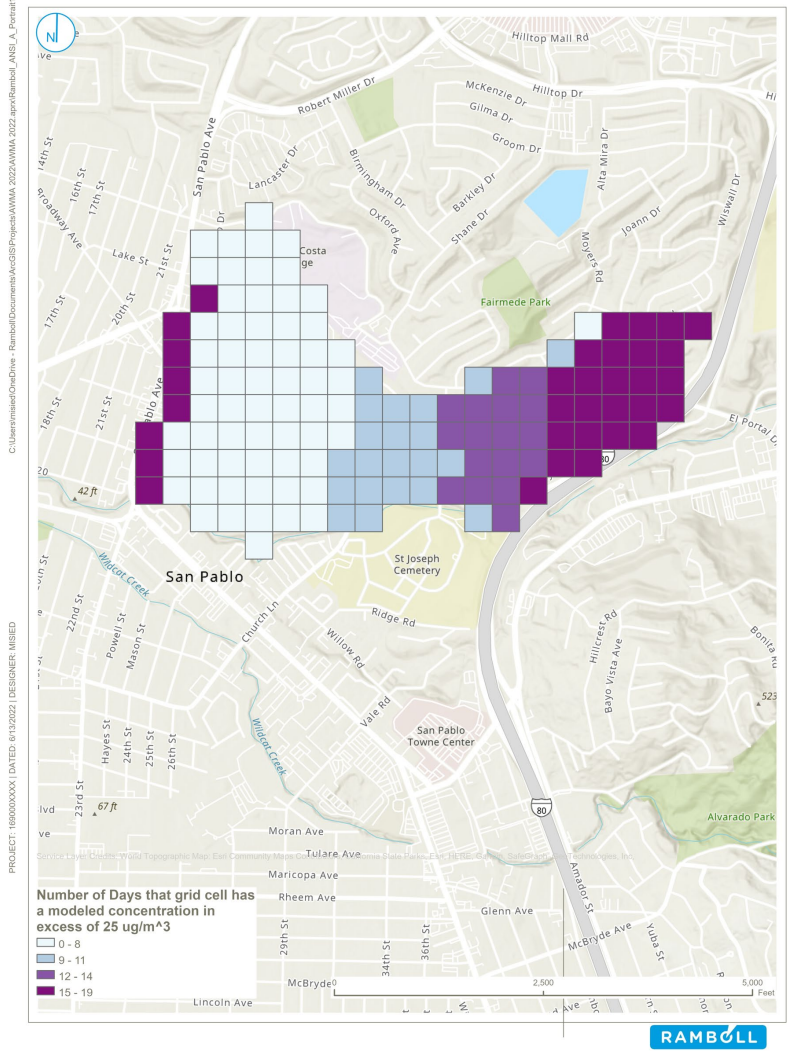
100-m x 100-m Spatial Resolution

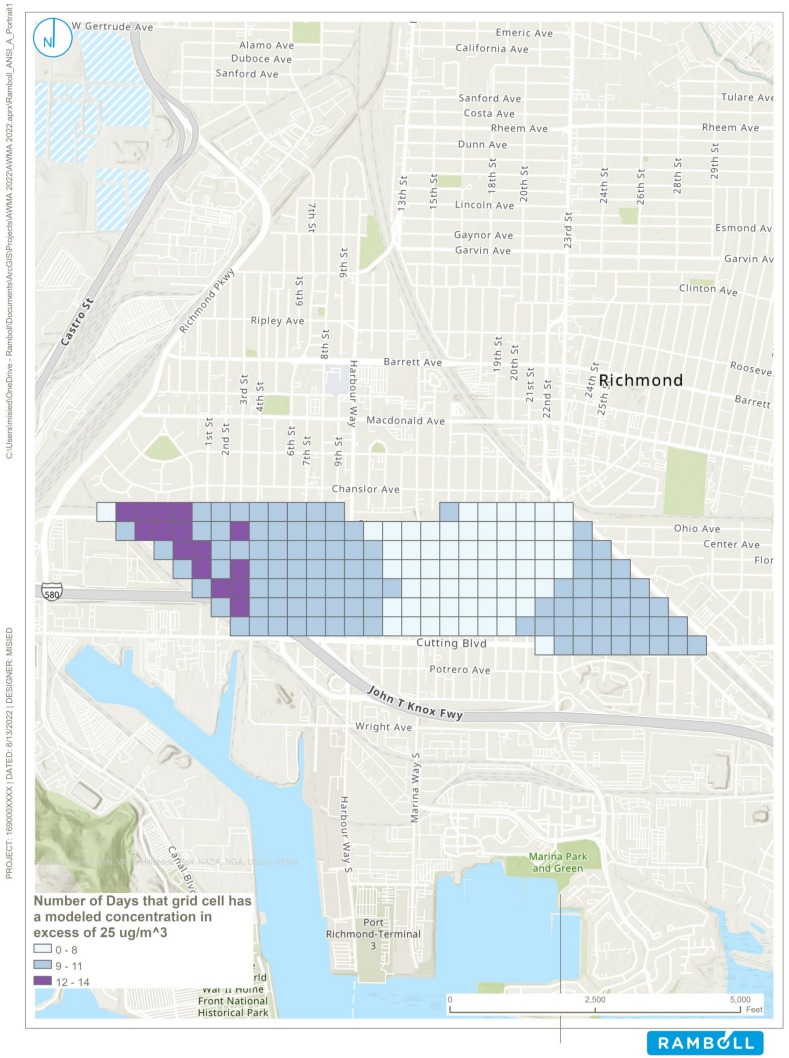
- Fused CAMx and Shairstreet air quality data at 100-m x 100-m resolution to capture spatial variability





Number of Days Shair Estimated $PM_{2.5}$ > 35 µg/m³





- Shair exhibits lots of spatial variability at 100-m resolution with high concentrations near roadways, ports and refineries