Fire & Smoke

How Next-Gen Air Quality Monitoring Infrastructure is Powering Wildfire Resilience

clarity

South Coast Air Quality Management District

LAUSD UNIFIED

Pepperwood PRESERVE

Photo: Ryan Ferrell, Pepperwood Preserve

Sean Wihera

VP, Business Development & Partnerships

Clarity Movement Co.

clarity

Fire & Smoke

How Next-Gen Air Quality Monitoring Infrastructure is Powering Wildfire Resilience

Agenda

40 min Presentations by panelists

20 min Panel discussion and Q&A

Please submit questions for the Q&A via Zoom Q&A feature!

Welcome!

Moderator

Sean Wihera

VP, Business Development & Partnerships

Clarity Movement

Levi Stanton

Lead Solutions Engineer

Clarity Movement

Carlos Torres

Director, OEHS

Los Angeles Unified School District (LAUSD)

Scott Epstein

Planning & Rules Manager

South Coast AQMD

Ryan Ferrell, MS

Sentinel Site Manager

Pepperwood Preserve

clarity

Levi Stanton

Lead Solutions Engineer
Clarity Lab

The pilot process to define and meet the technical considerations for air quality sensors on FASM

AirNow Fire and Smoke Map

Pilot process to include additional $PM_{2.5}$ sensors on the map

clarity

Thank you, Ron! Congrats on Retirement!

Ron Evans

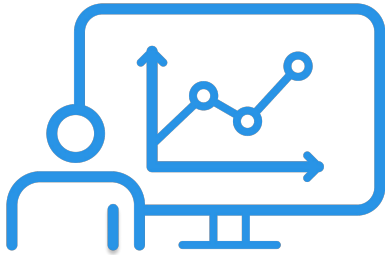
Thank you for your leadership on this pilot, and 45 years of service at EPA!

Why provide Clarity data on the Fire & Smoke Map?

Expand access to trustworthy AQ data

Part of our mission to make high-quality environmental information more widely available.

"global data" icon by Fran Couto from The Noun Project.



Support data sharing for Clarity clients

Help customers share data transparently and equitably, especially in areas underrepresented by existing networks.

Partner with EPA to improve public sensor data

Public-private partnership to improve how sensor data serves the public and supports informed decision-making.

"public private partnership" icon by diyah farida from The Noun Project.

The road to defining FASM technical considerations

November 2022
Initiated pilot process with EPA

May 2023
Open API v1 released

August 2024
Open API v2 released

January 2025
LA sensors added to FASM to support fire emergency

April 2025
Clarity Global Calibration v2.1

July 2025
MTA signed by all parties

Summer 2024
Clarity establishes collocations across country

Iterate on data targets & analyses

FASM Inclusion Criteria and Requirements

A weight of evidence approach

clarity

"Apples-to-Apples" $PM_{2.5}$ Data	Commitments	Deliverables
Excellent NowCast AQI categorization accuracy across all AQI categories	Provide calibrated and quality assured data without cost to USEPA or USFS	Optimized and open real-time API
EPA-format testing reports in a range of climates meeting EPA performance targets	Work closely with USEPA and USFS to maintain API reliability	Sensor Networks Characteristics (size, scope, locations, etc.)
Comprehensive and documented automated quality control	Communicate quality control, calibration, firmware, or hardware changes	Final, public-facing report demonstrating all evidence

Developing the V2.1 Global calibration

623
Node-S sensors

84
Unique cities

98
Reference sites

>6 million
Measurements

Evolution of Clarity's Global $PM_{2.5}$ Calibration

Los Angeles Case Study - Performance of Global Calibrations during January wildfires

clarity

Hourly

Node ID	Reference Site Name	Batch	Period Start	Period End	Dependent	Slope	Intercept (µg/m³)	R^2	RMSE (µg/m³)	MAE (µg/m³)	Pairwise Complete Observations	Pairwise Completeness (%)
AWN6HYWP	Los Angeles - N. Main Street	Permanent Collocation	2024-11-01T00:00:00Z	2025-02-01T00:00:00Z	Raw	1.36	6.99	0.76	20.92	14.87	2194	99.37
AWN6HYWP	Los Angeles - N. Main Street	Permanent Collocation	2024-11-01T00:00:00Z	2025-02-01T00:00:00Z	Global v1	0.66	2.95	0.78	9.85	4.62	2194	99.37
AWN6HYWP	Los Angeles - N. Main Street	Permanent Collocation	2024-11-01T00:00:00Z	2025-02-01T00:00:00Z	Global v2	0.84	2.93	0.92	5.65	3.24	2194	99.37
AWN6HYWP	Los Angeles - N. Main Street	Permanent Collocation	2024-11-01T00:00:00Z	2025-02-01T00:00:00Z	Global v2.1	0.91	1.76	0.94	4.77	3.18	2194	99.37

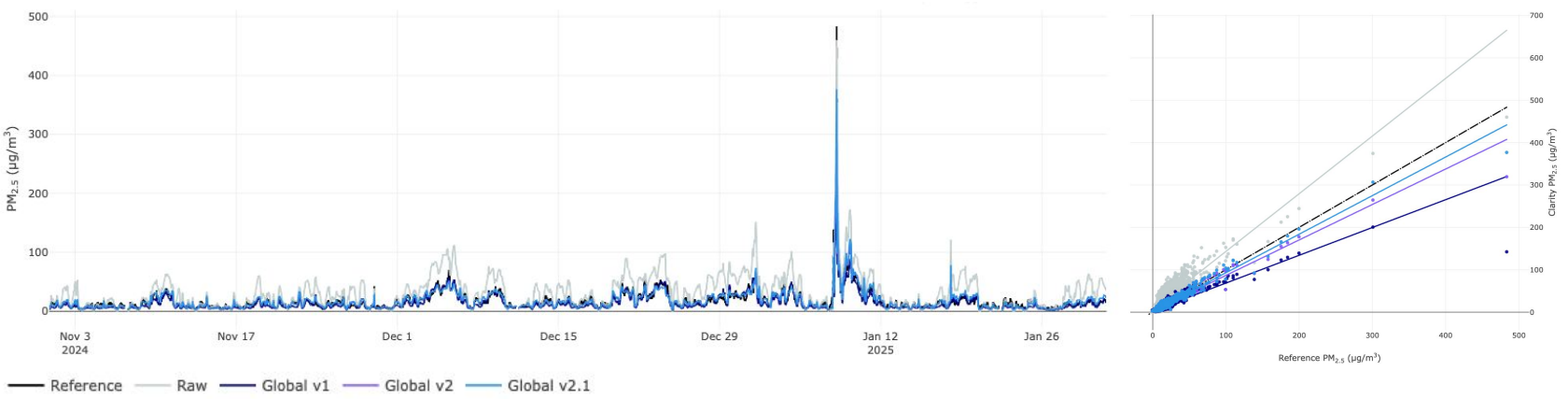
Daily

Node ID	Reference Site Name	Batch	Period Start	Period End	Dependent	Slope	Intercept (µg/m³)	R^2	RMSE (µg/m³)	MAE (µg/m³)	Pairwise Complete Observations	Pairwise Completeness (%)
AWN6HYWP	Los Angeles - N. Main Street	Permanent Collocation	2024-11-01T00:00:00Z	2025-02-01T00:00:00Z	Raw	1.54	3.62	0.81	18.52	13.86	91	98.91
AWN6HYWP	Los Angeles - N. Main Street	Permanent Collocation	2024-11-01T00:00:00Z	2025-02-01T00:00:00Z	Global v1	0.81	0.22	0.91	5.57	3.73	91	98.91
AWN6HYWP	Los Angeles - N. Main Street	Permanent Collocation	2024-11-01T00:00:00Z	2025-02-01T00:00:00Z	Global v2	0.94	1.05	0.96	2.81	2.01	91	98.91
AWN6HYWP	Los Angeles - N. Main Street	Permanent Collocation	2024-11-01T00:00:00Z	2025-02-01T00:00:00Z	Global v2.1	0.98	0.38	0.97	2.56	1.95	91	98.91

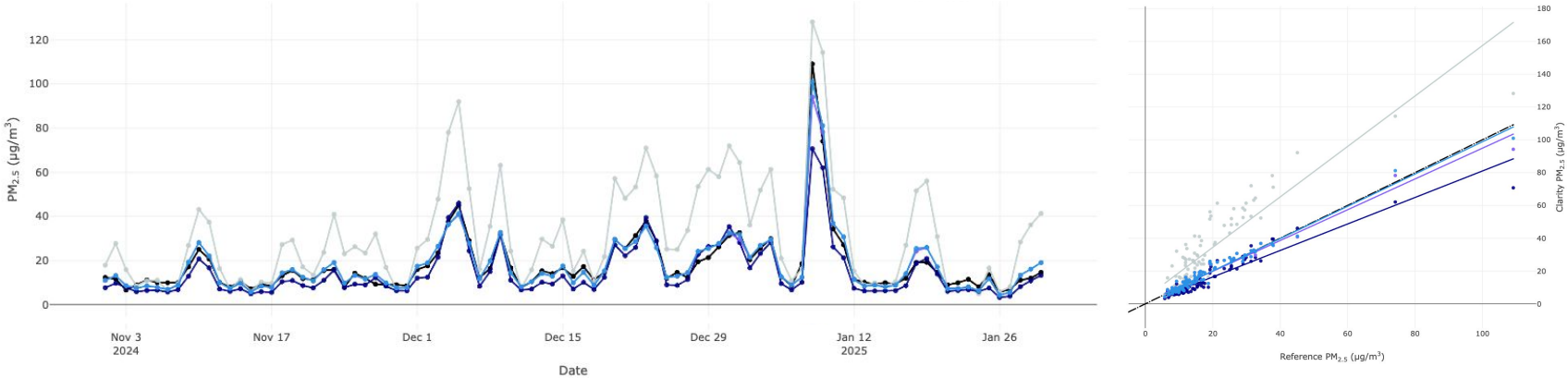
Evolution of Clarity's Global $PM_{2.5}$ Calibration

Los Angeles Case Study - Performance of Global Calibrations during January wildfires

Hourly



Daily



Commerce City, Colorado

Testing Report - $PM_{2.5}$ Base Testing

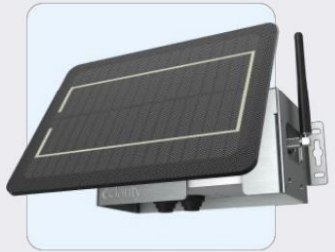
Clarity Node-S

This report reflects the v2.1 Global $PM_{2.5}$ Calibration performance

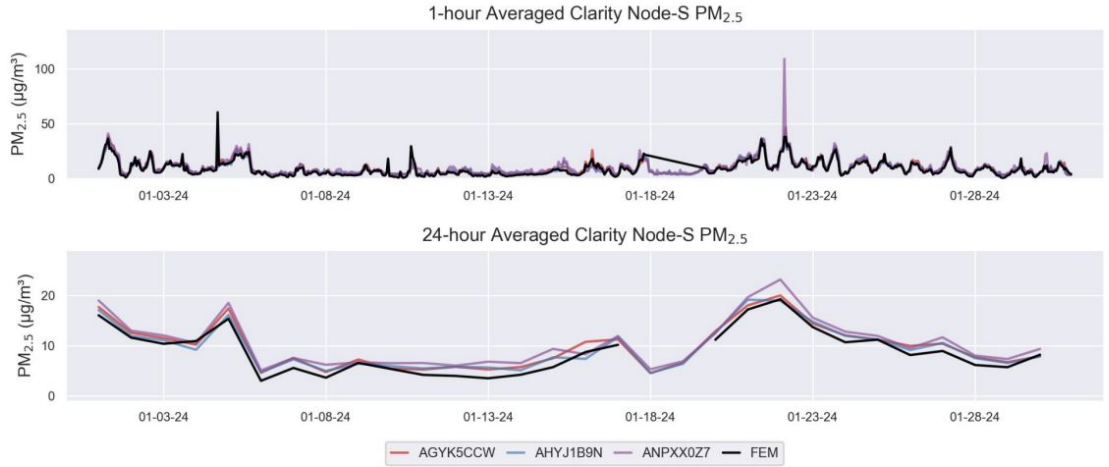
Commerce City, CO

Colorado Department of Public Health and Environment

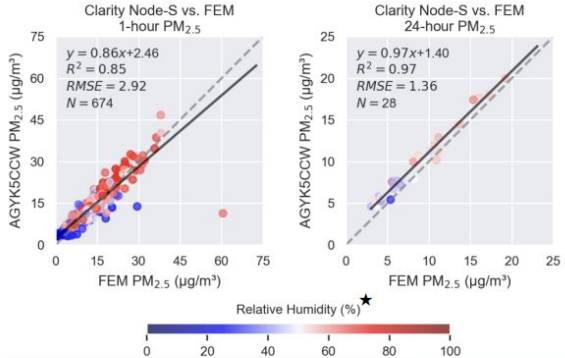
January 2024



Time Series Plots



Scatter Plots: Comparison to FRM/FEM



Range of FRM/FEM concentrations over duration of base test (µg/m³)	[1-hr] 0.5-60.5, avg: 8.8, [24-hr] 3.0-19.2, avg: 8.9
Number of 24-hr periods in FRM/FEM monitor measurements with a goal concentration ≥ 25 µg/m³	0

New York City, NY

Testing Report - $PM_{2.5}$ Base Testing

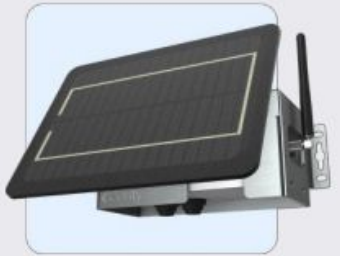
Clarity Node-S

This report reflects the v2.1 Global $PM_{2.5}$ Calibration performance

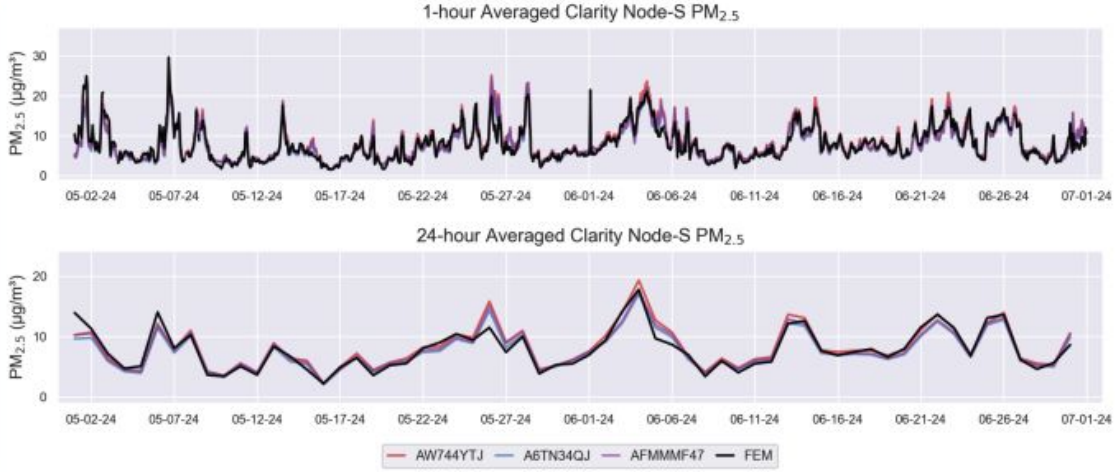
New York City, NY

New York Department of Environmental Conservation

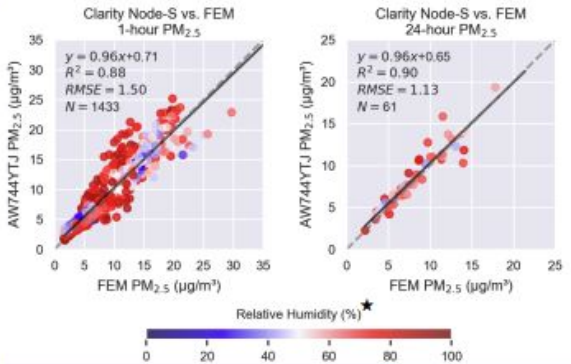
May 2024 – June 2024



Time Series Plots



Scatter Plots: Comparison to FRM/FEM



Range of FRM/FEM concentrations over duration of base test (µg/m³)	[1-hr] 1.6-29.7, avg: 7.9, [24-hr] 2.2-17.8, avg: 7.9
Number of 24-hr periods in FRM/FEM monitor measurements with a goal concentration ≥ 25 µg/m³	0

Reno, NV

Testing Report - $PM_{2.5}$ Base Testing

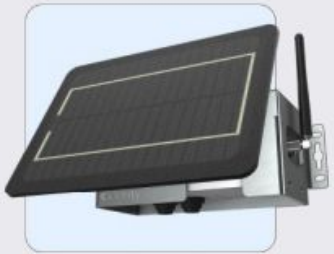
Clarity Node-S

This report reflects the v2.1 Global $PM_{2.5}$ Calibration performance

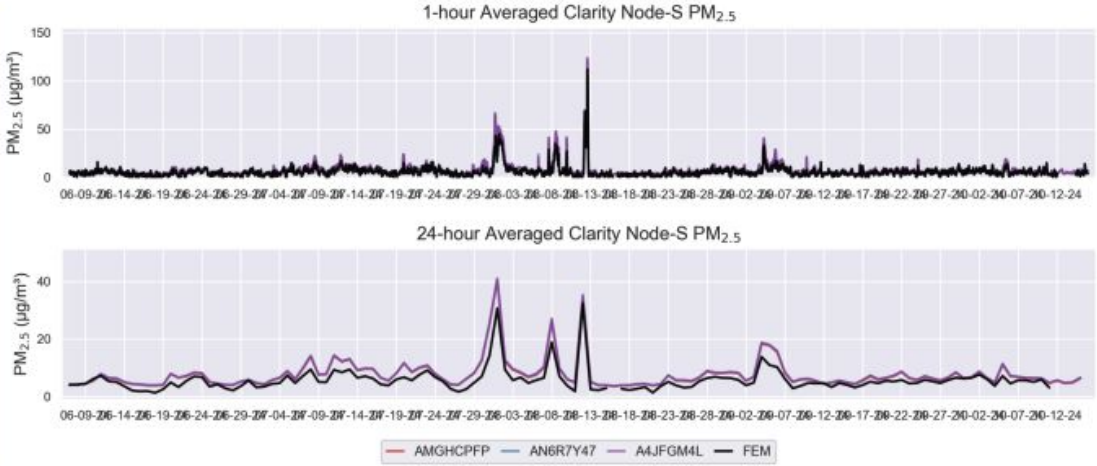
Reno, NV

Northern Nevada Public Health Air Quality Management Division

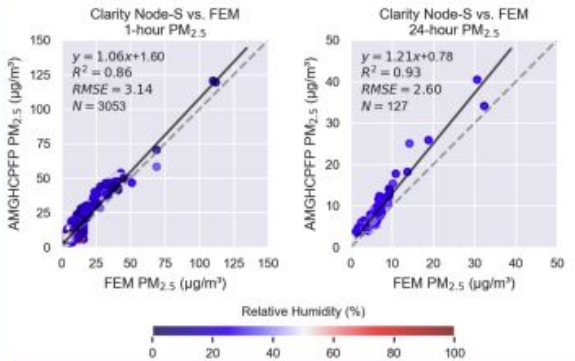
June 2024—October 2024



Time Series Plots



Scatter Plots: Comparison to FRM/FEM



Range of FRM/FEM concentrations over duration of base test (µg/m³)	[1-hr] -3.0-112.0, avg: 5.6, [24-hr] 1.3-32.3, avg: 5.7
Number of 24-hr periods in FRM/FEM monitor measurements with a goal concentration ≥ 25 µg/m³	2

Roosevelt, UT

Testing Report - $PM_{2.5}$ Base Testing

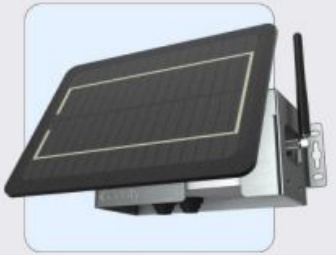
Clarity Node-S

This report reflects the v2.1 Global $PM_{2.5}$ Calibration performance

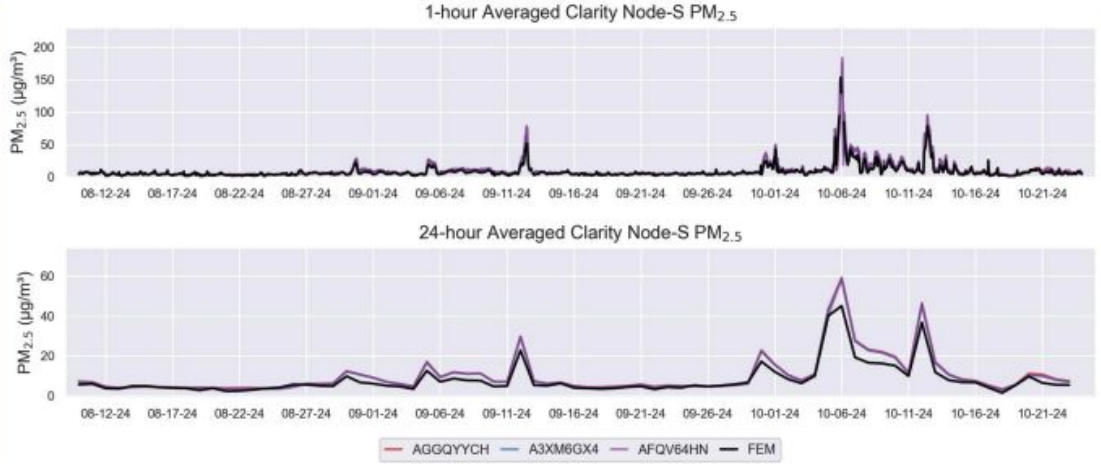
Roosevelt, UT

Utah Department of Environmental Quality

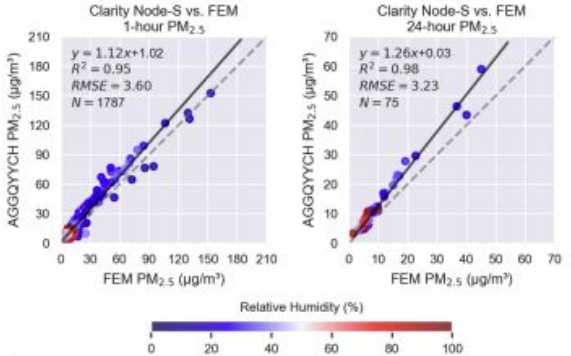
August 2024—October 2024



Time Series Plots



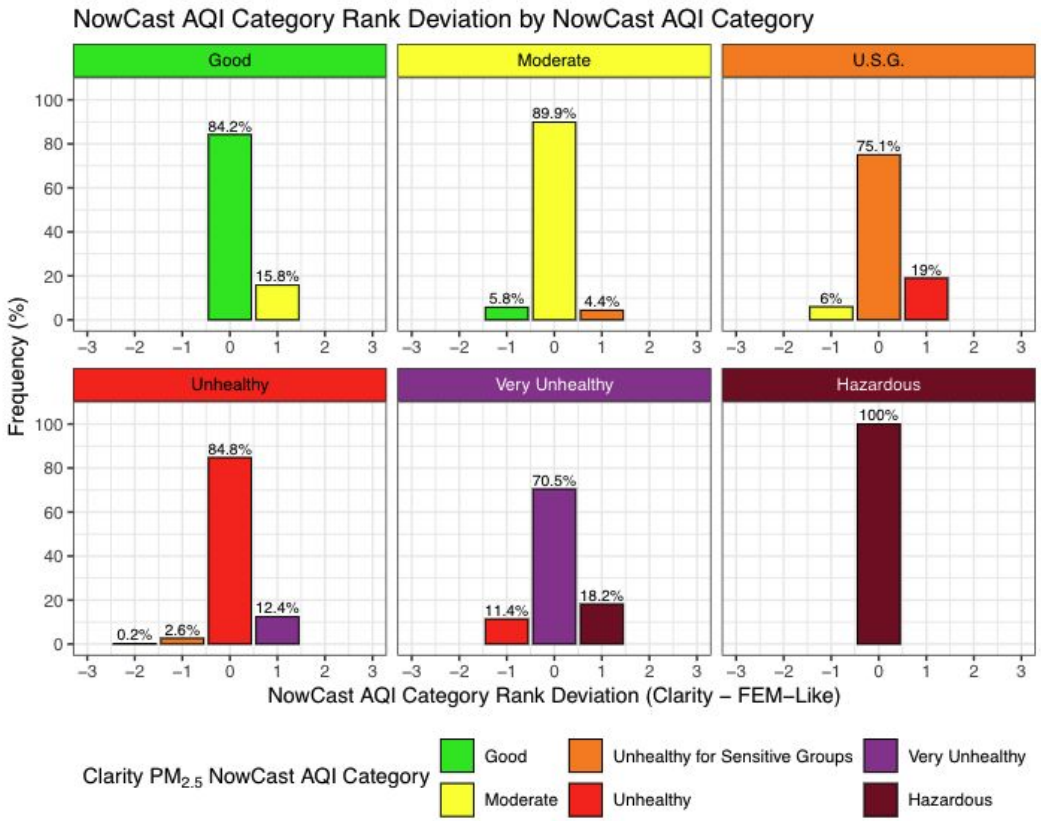
Scatter Plots: Comparison to FRM/FEM



Range of FRM/FEM concentrations over duration of base test (µg/m³)	[1-hr] 0.0-153.1, avg: 7.9, [24-hr] 1.4-45.1, avg: 8.0
Number of 24-hr periods in FRM/FEM monitor measurements with a goal concentration ≥ 25 µg/m³	3

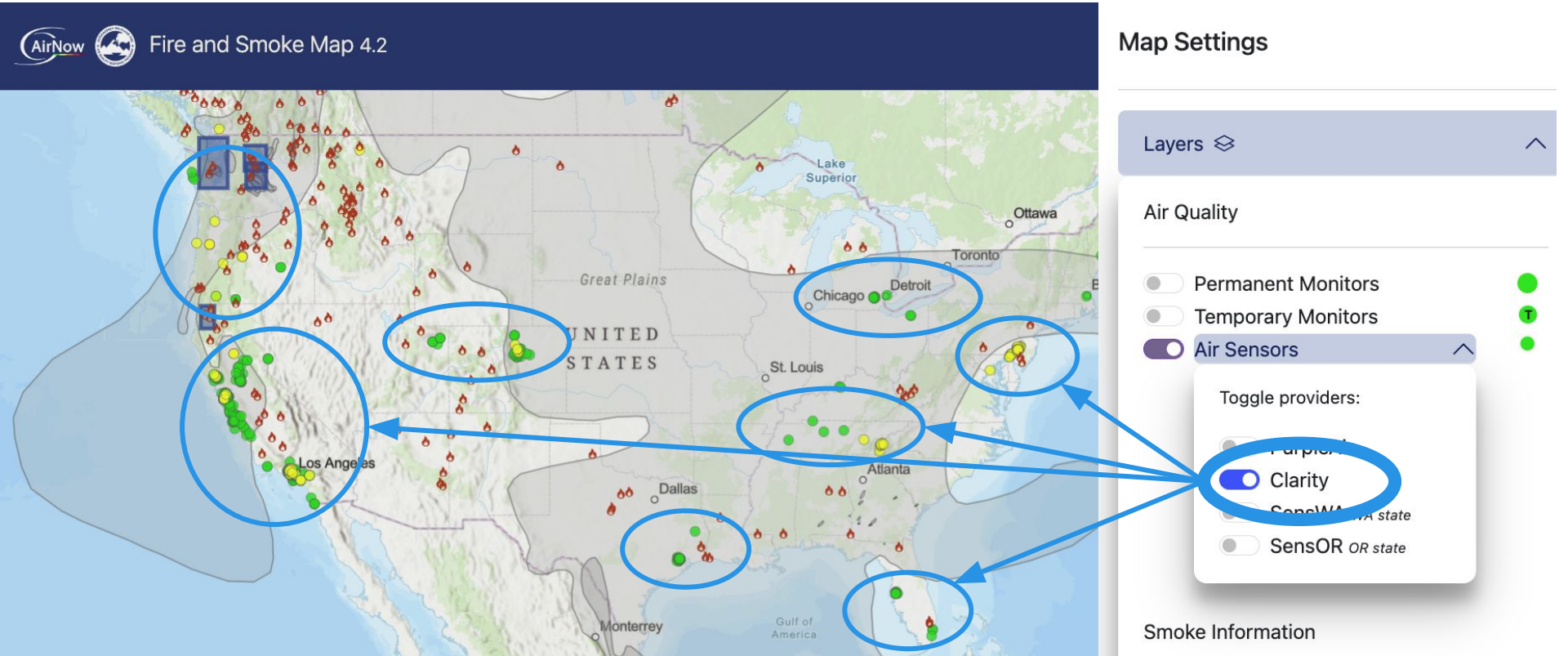
Demonstrating performance across AQI range

Clarity worked with partners to establish collocations in wildfire-prone areas



Clarity officially added to FASM in July 2025

650+ data points, with hundreds more ready to be added

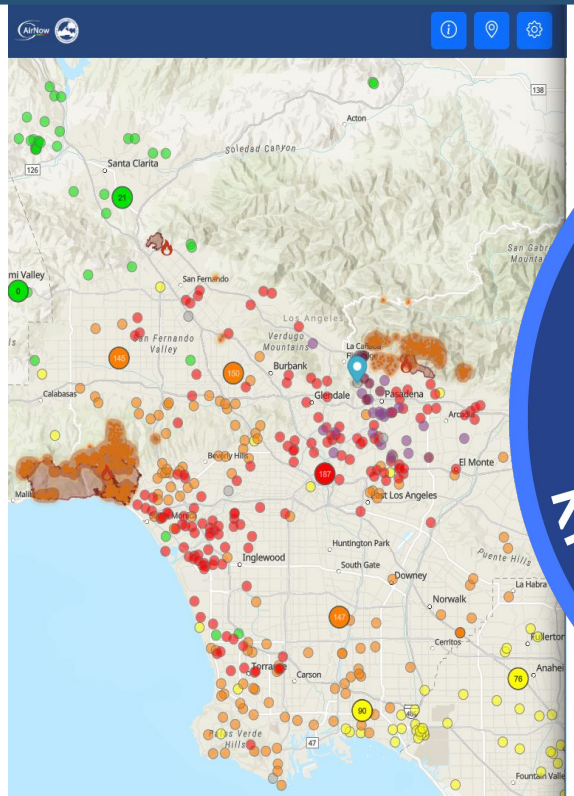


LAUSD Know Your Air Network on FASM

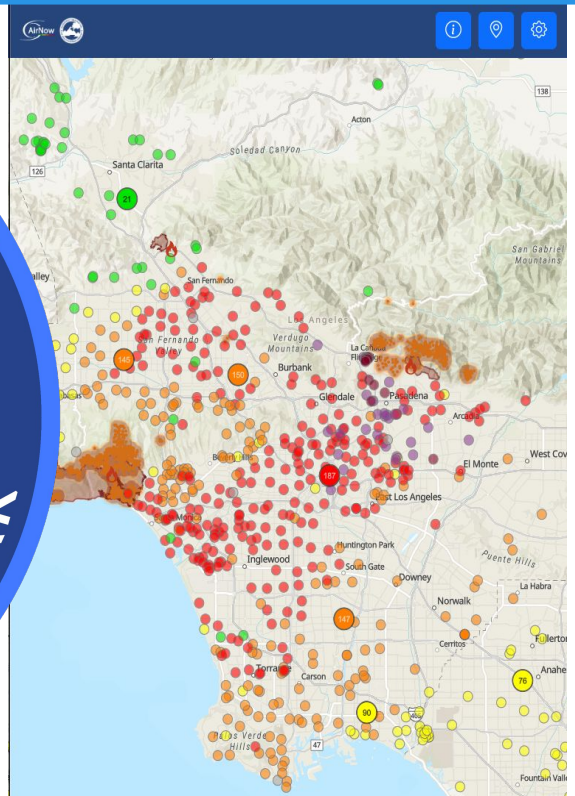
Filling in the gaps during Los Angeles wildfires

clarity

Without KYAN



With KYAN



LOS ANGELES UNIFIED
KNOW YOUR AIR NETWORK

LOS ANGELES UNIFIED SCHOOL DISTRICT: KNOW YOUR AIR NETWORK 2.0

09/26/2025

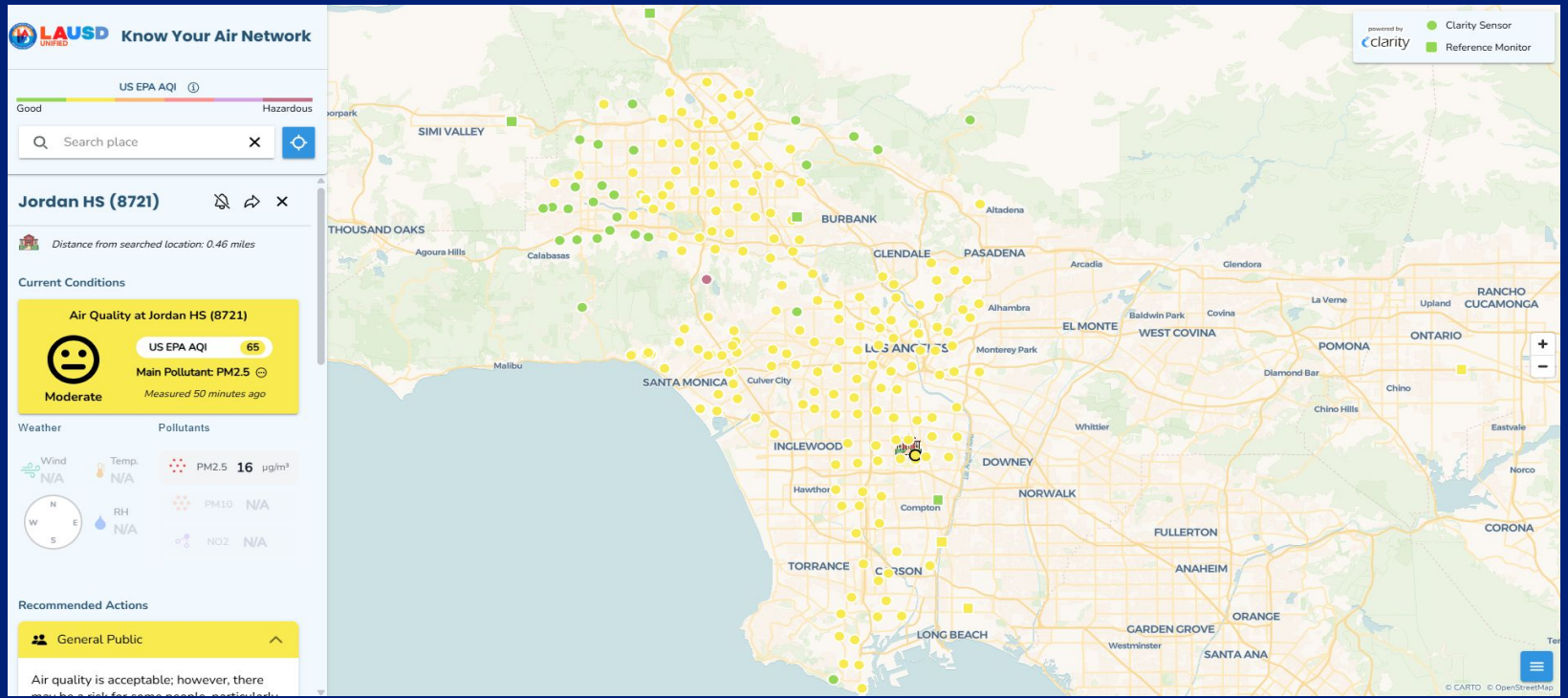
OUR WHY

- Increase in the frequency and intensity of wildfires during the past several years.
- Creating unsafe air pollution levels at our schools
- Los Angeles region continues to have some of the worst air pollution in the country.
- LAUSD uses its air network during emergency events such as wildfires and poor air quality episodes to determine what actions need to be taken
- Better informed decisions for individual schools

LAUSD UNIFIED

What is the Know Your Air Network?

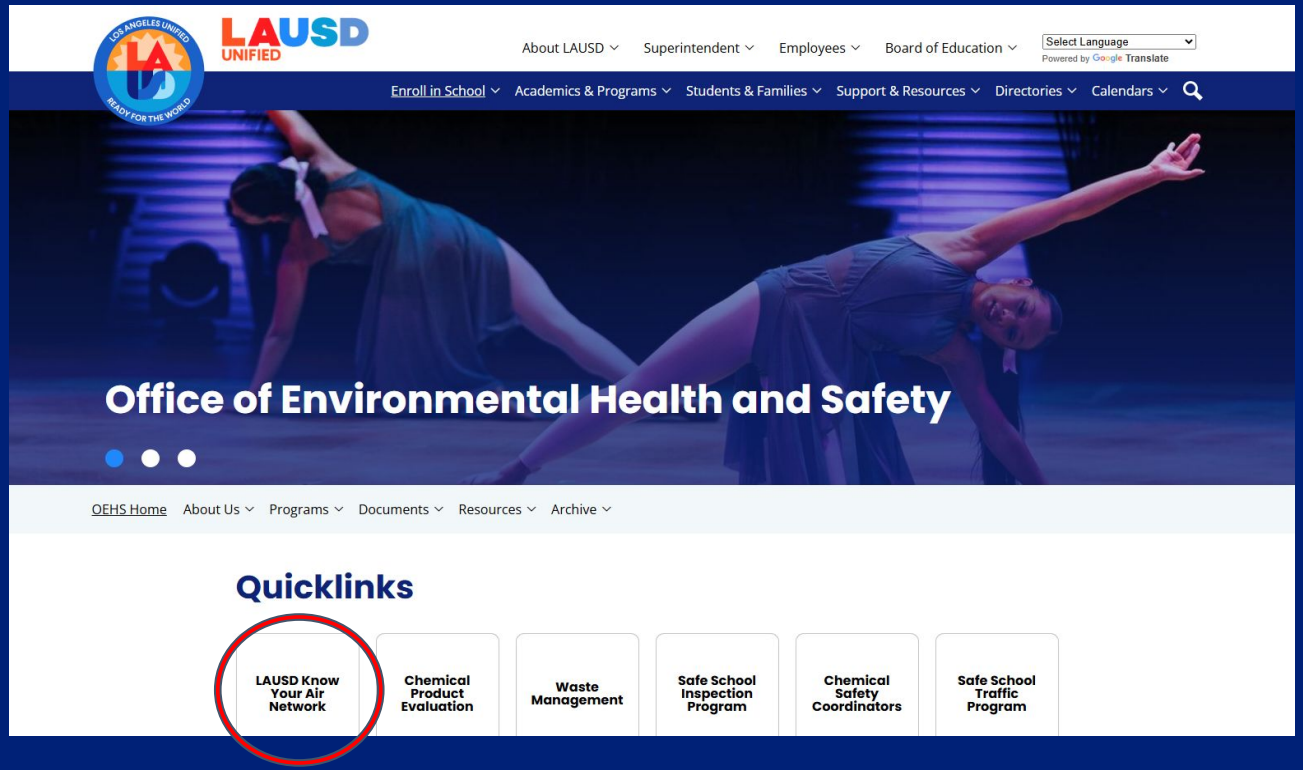
One of the largest school-based air monitoring network in the U.S.



LAUSD UNIFIED

Real-Time Access at OEHS.LAUSD.ORG

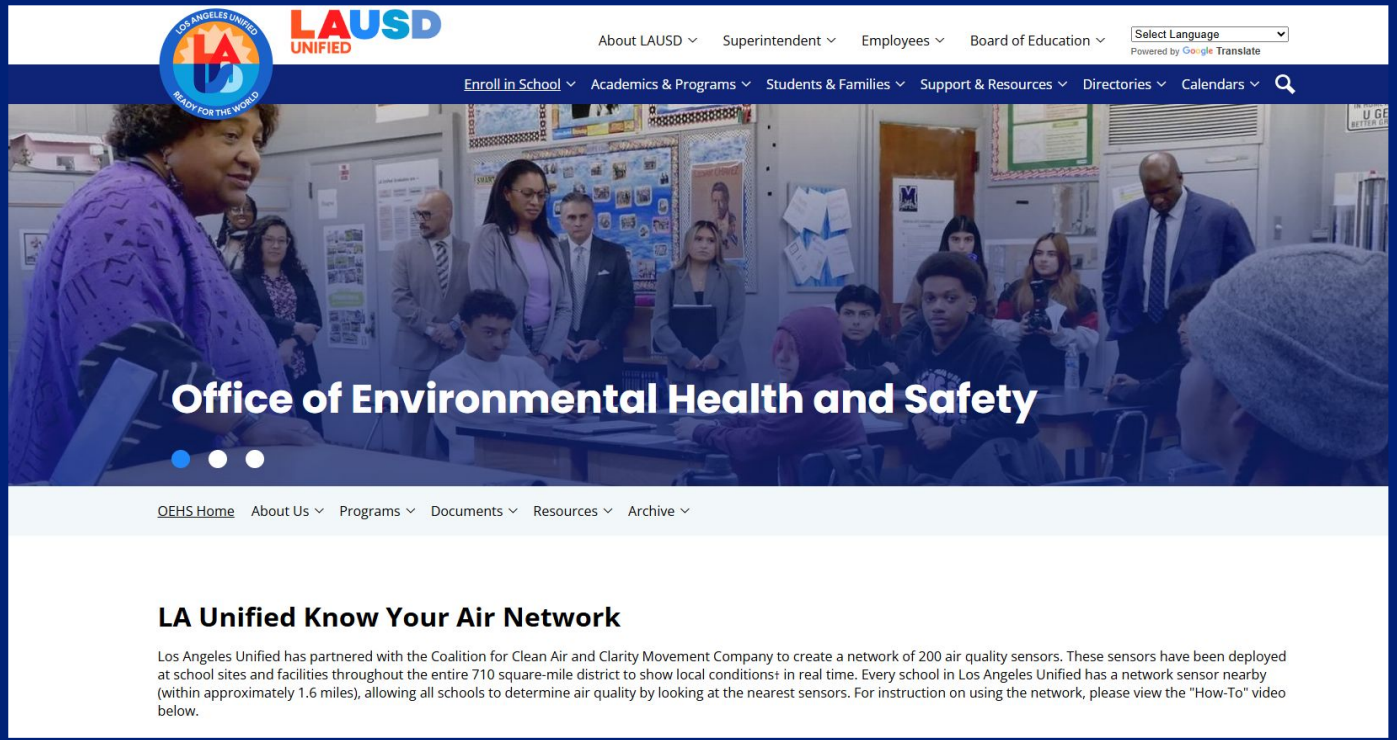
Data every 3-5 minutes



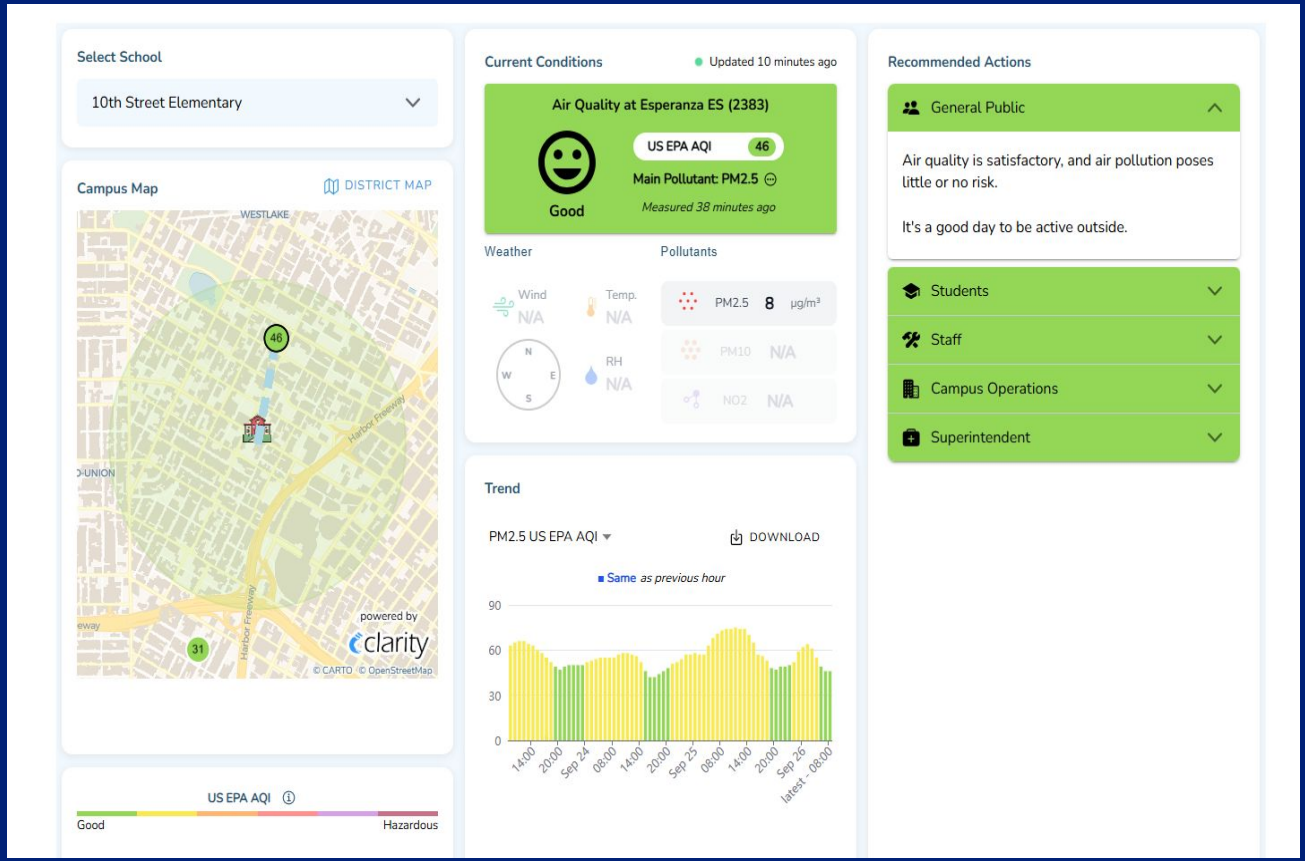
LAUSD UNIFIED

Real-Time Access

Data every 3-5 minutes



How Does OEHS Use This Data?



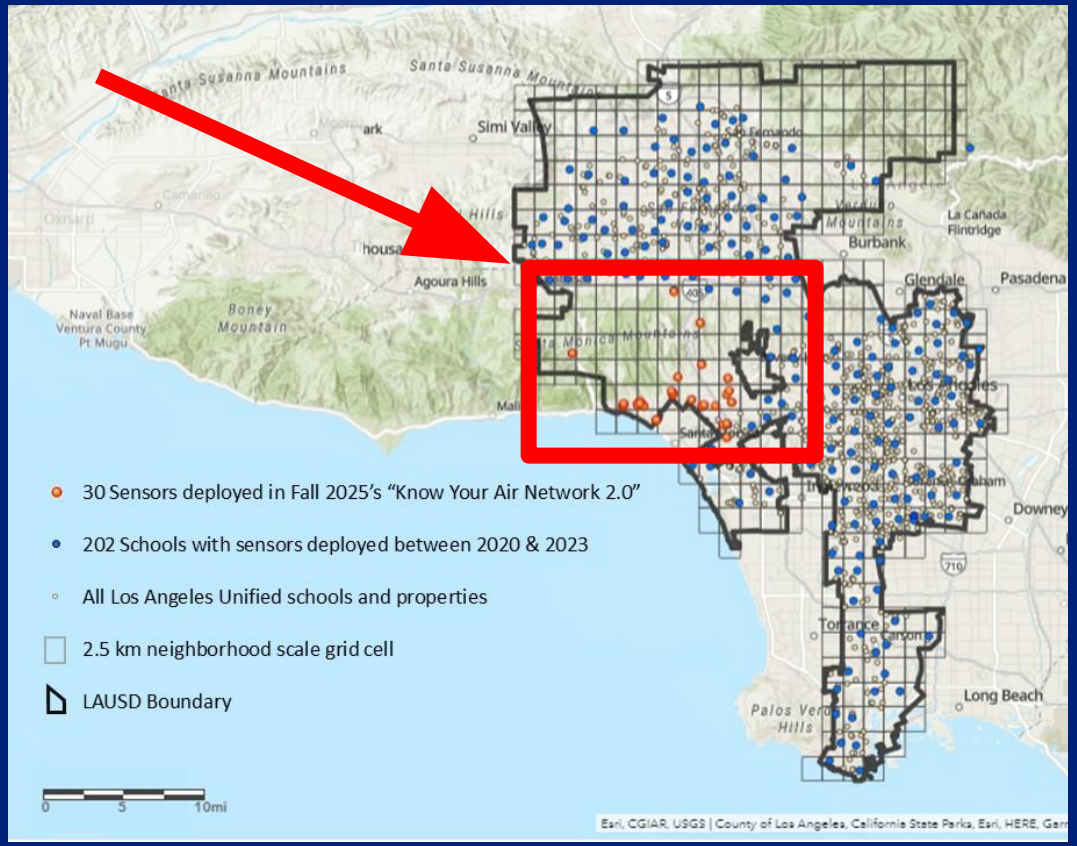
LAUSD UNIFIED

Why KYAN 2.0?

Lessons from the January 2025 Fires

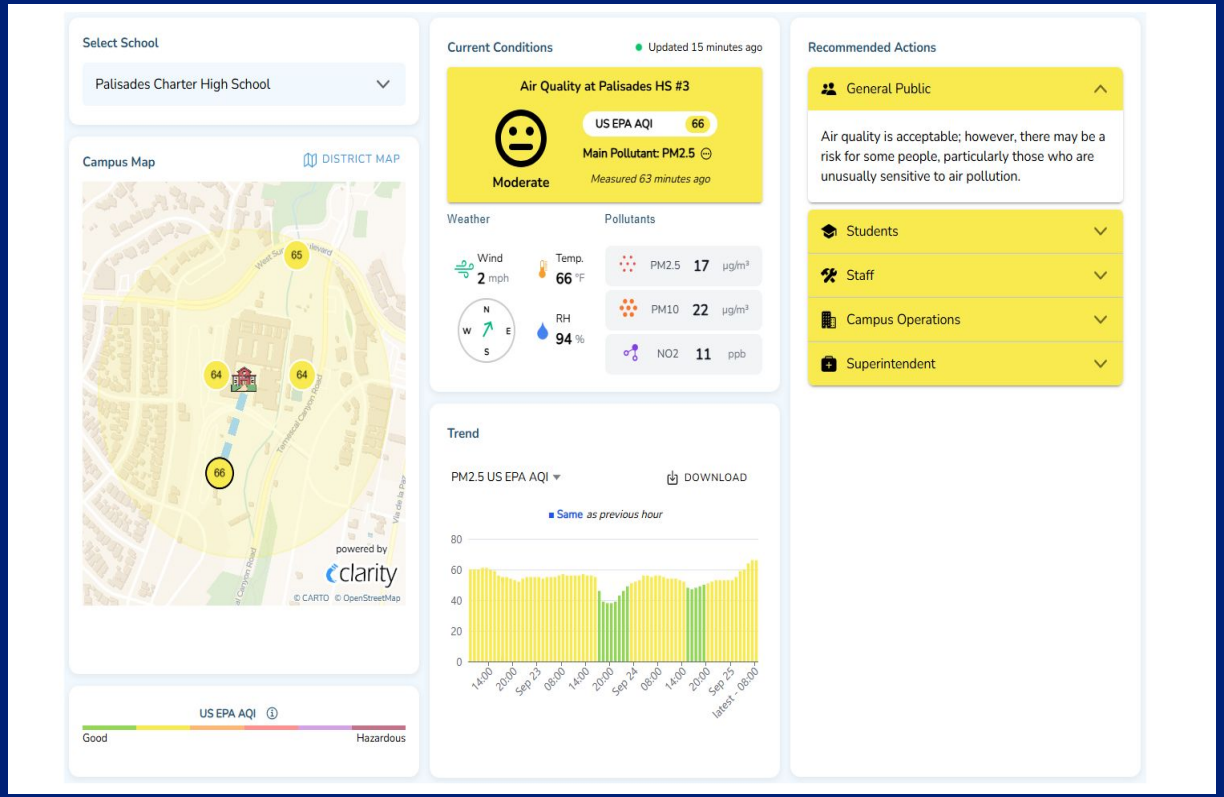
KYAN 2.0: A Direct Response to the 2025 Wildfires

- January 2025 wildfires revealed need for expanded monitoring beyond $PM_{2.5}$
- LAUSD worked with Clarity to expedite development of new PM_{10} "Dust Modules"
- Dust Modules and Wind & Meteorological Modules installed in 30 sensitive sites ahead of the start of the 2025-2026 school year



LAUSD UNIFIED

What do the sensors measure?



LAUSD UNIFIED

Air Quality Index

EPA's standard for reporting air quality

AQI color-coded scale (0–500)

- **Green → Good**
- **Yellow → Moderate**
- **Orange → Unhealthy for Sensitive Groups**
- **Red → Unhealthy**
- **Purple → Very Unhealthy**
- **Maroon → Hazardous**

Daily AQI Color	Levels of Concern	Values of Index
Green	Good	0 to 50
Yellow	Moderate	51 to 100
Orange	Unhealthy for Sensitive Groups	101 to 150
Red	Unhealthy	151 to 200
Purple	Very Unhealthy	201 to 300
Maroon	Hazardous	301 and higher

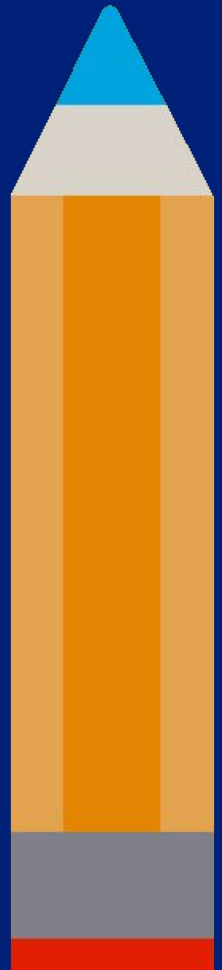
LAUSD UNIFIED

Broader Impact

A model for California and beyond

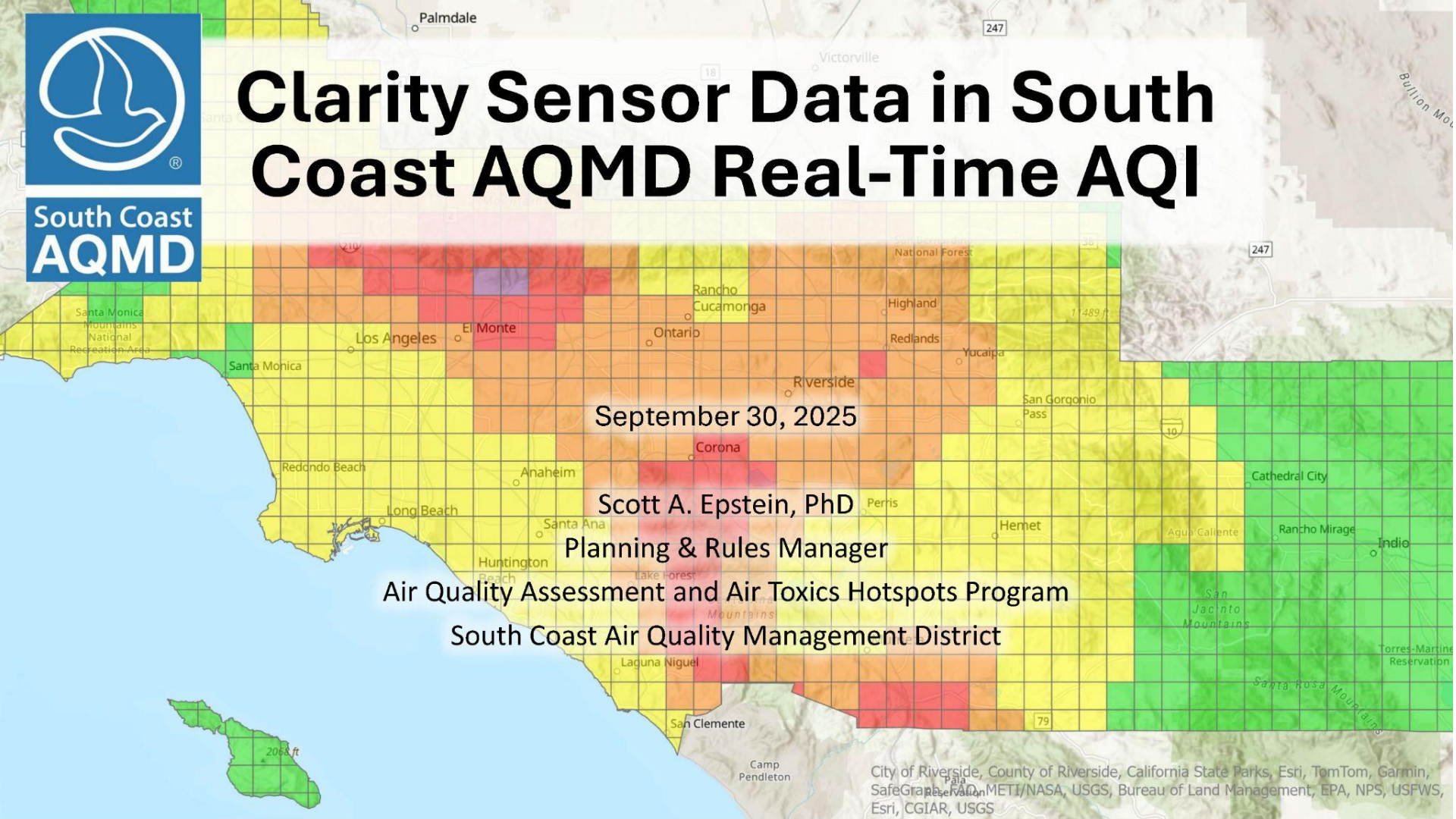
- **Spearheading air quality efforts**
- **STEM Education tool**
- **Provides support beyond wildfires!**

THANK YOU



LAUSD UNIFIED

Clarity Sensor Data in South Coast AQMD Real-Time AQI



September 30, 2025

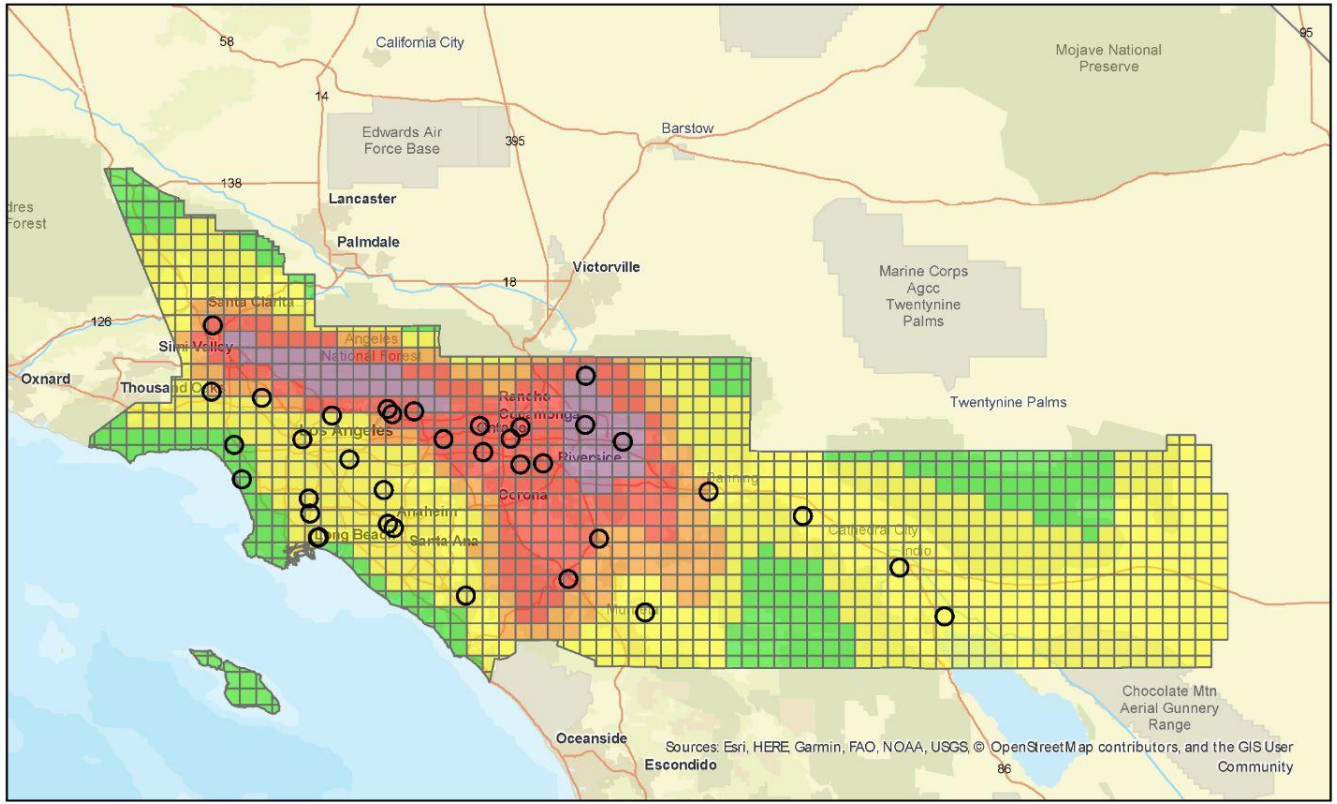
Scott A. Epstein, PhD

Planning & Rules Manager

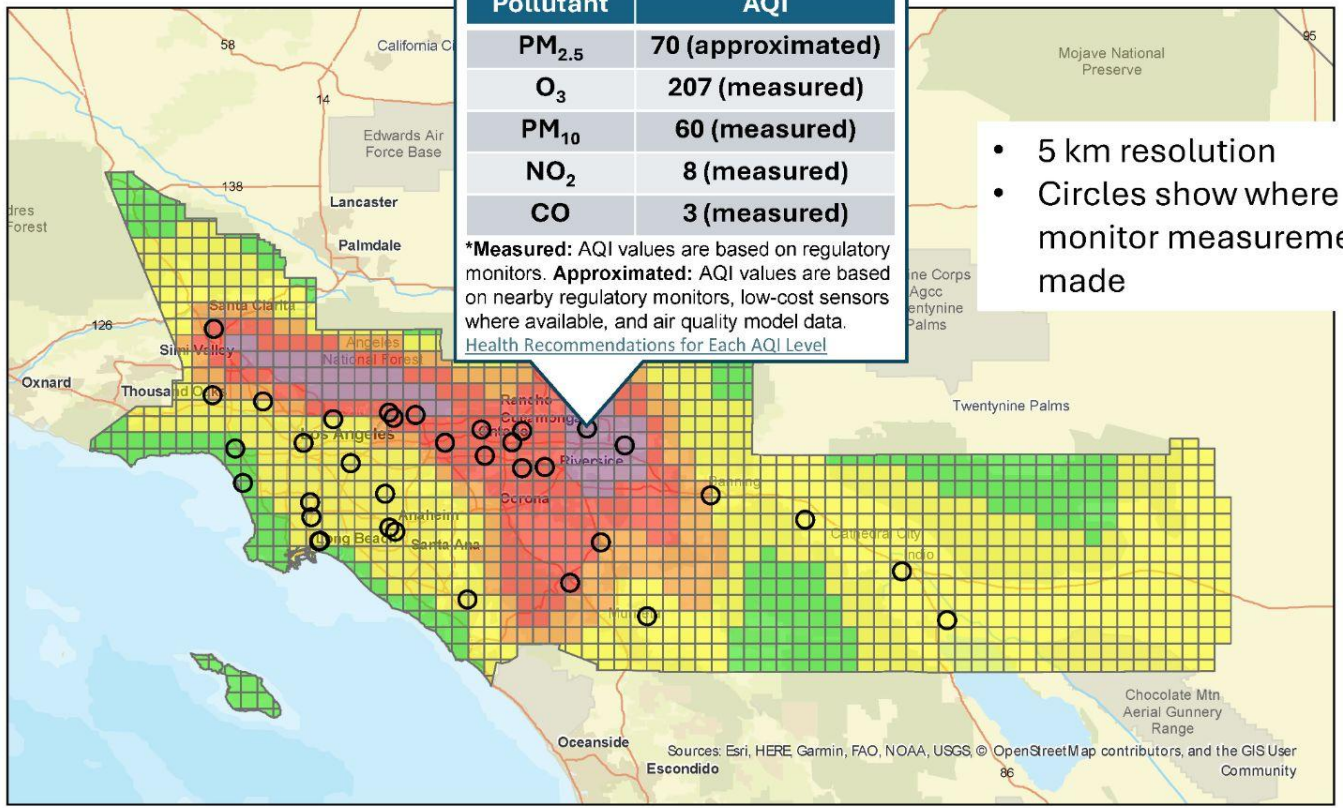
Air Quality Assessment and Air Toxics Hotspots Program

South Coast Air Quality Management District

Real-Time AQI Map (www.aqmd.gov/aqimap)

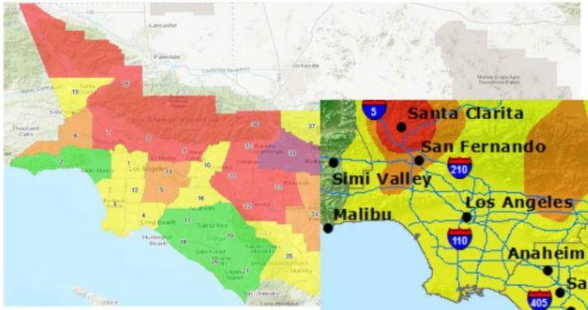


Real-Time AQI M d.gov/aqimap)



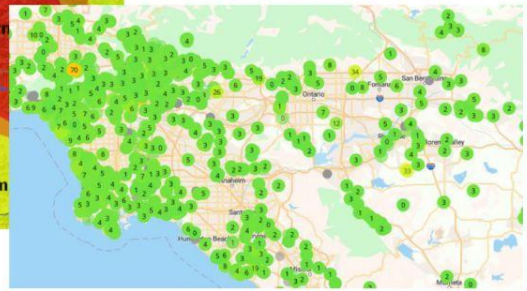
Advantages of Gridded AQI Map

Historical "Proxy Method"

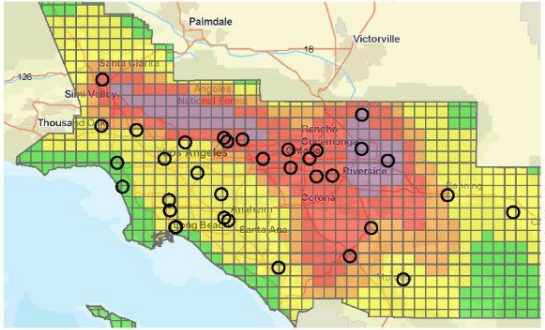


AirNow

PurpleAir



Gridded AQI



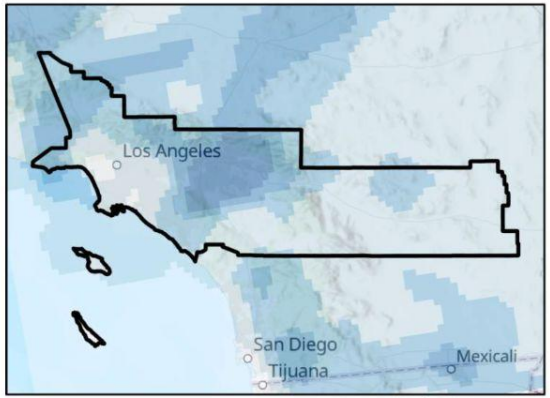
- ✓ Consumer-grade sensor data is appropriately interpreted
- ✓ It is clear where monitors are located and where data is approximated through interpolation
- ✓ Interpolation scheme accounts for complex terrain because it blends in air quality model
- ✓ Public doesn't need to look at multiple maps or consider different types of data. Especially important when multiple pollutants can drive AQI
- ✓ Resolution small enough to accurately represents neighborhood scale events

South Coast AQMD

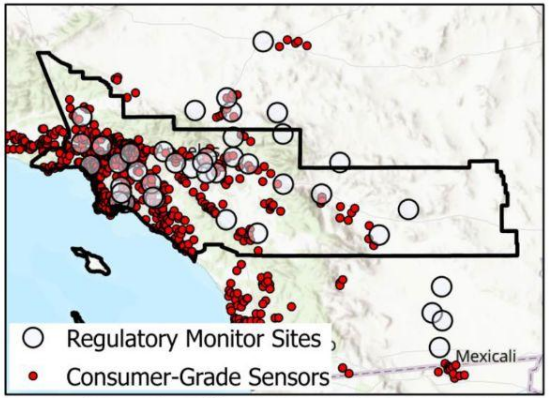
How the AQI Map Works

AQI Map uses sensor data to fill in gaps between monitors:
~780 PurpleAir $PM_{2.5}$, ~225 Clarity $PM_{2.5}$ sensors

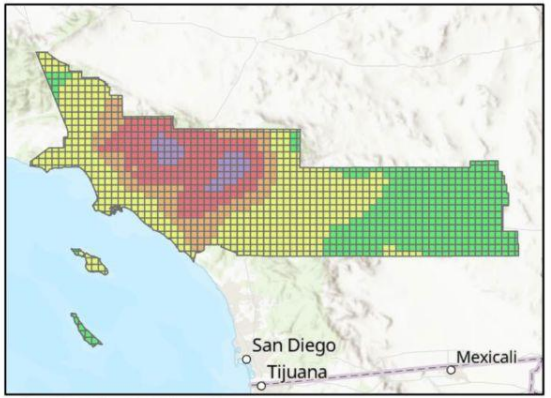
Gridded Model Data



Monitor and Consumer-Grade Sensor Data



Gridded AQI



Loma Linda University, UC Riverside, County of Riverside, California State Parks, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, Esri, USGS

Pollutant	Method	Far from monitors	Near monitors
$PM_{2.5}$	Fill in gaps between monitors using model and consumer-grade sensor data	Models and consumer-grade sensor data drive concentration	Monitor data drives concentration
O_3	Fill in gaps between monitors using model	Models drive concentration	
PM_{10}, NO_2, CO	Natural neighbor interpolation	Monitor data drives concentration	

Schulte, N., Li, X., Ghosh, J.K., Fine, P.M., Epstein, S.A. **Responsive High-Resolution Air Quality Index Mapping Using Model, Regulatory Monitor, and Sensor Data in Real-Time**, 2020, *Environmental Research Letters*, **15** 1040a7

South Coast AQMD

Treatment of Consumer-Grade Sensor PM2.5 Data

Download Sensor Data

PurpleAir

Clarity

Quality Control PurpleAir

Compare measurements from the two channels in each PurpleAir using statistical criteria

Calibrate PurpleAir

Using collocated reference monitor data and correction for relative humidity

Combine Sensors to Estimate Average Concentration in Grid Cell

To mitigate potential bias caused by hyperlocal sensors, we average sensors in similar geographical areas

Calculate NowCast and AQI

Hourly averages processed to calculate NowCast AQI:

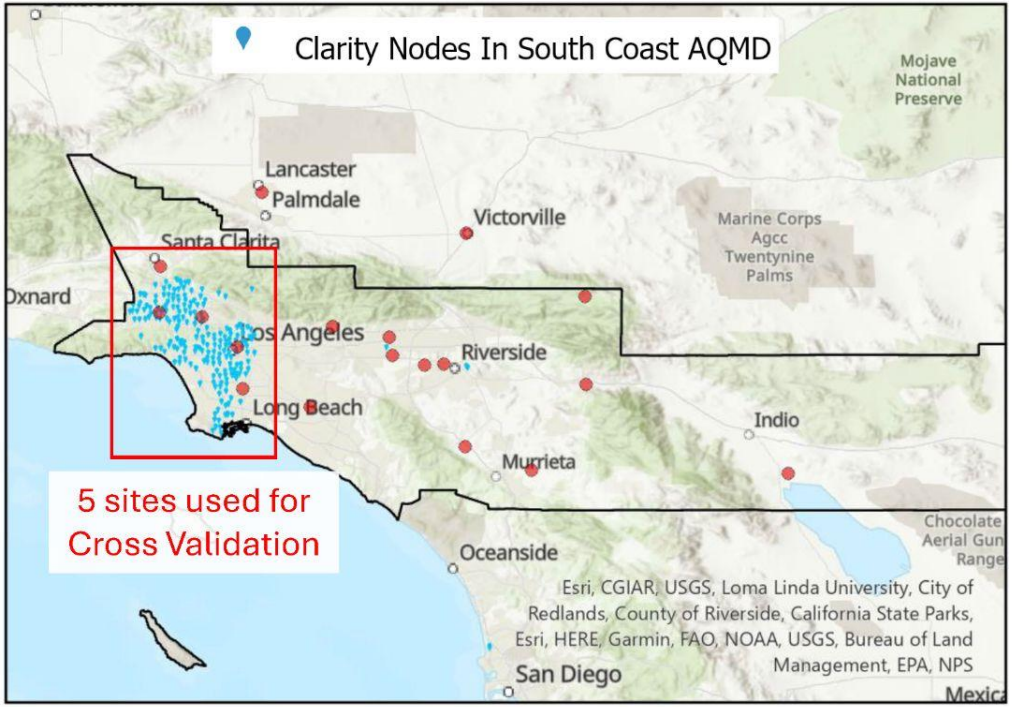
- NowCast is a weighted moving average, used to link hourly data to exposure over 24-hour period and to the Air Quality Index (AQI)
- NowCastFactSheet2D_EPA.pub

Clarity already Quality Controlled/Calibrated by manufacturer

South Coast AQMD

Clarity Sensor Blending in Real-Time AQI

- Wrote code to load hourly data from the Clarity open data API
- Quality control is done by Clarity
- Used in Kriging calculation to weight the data based on measurement error variance
- Analyzed performance using leave one out cross validation



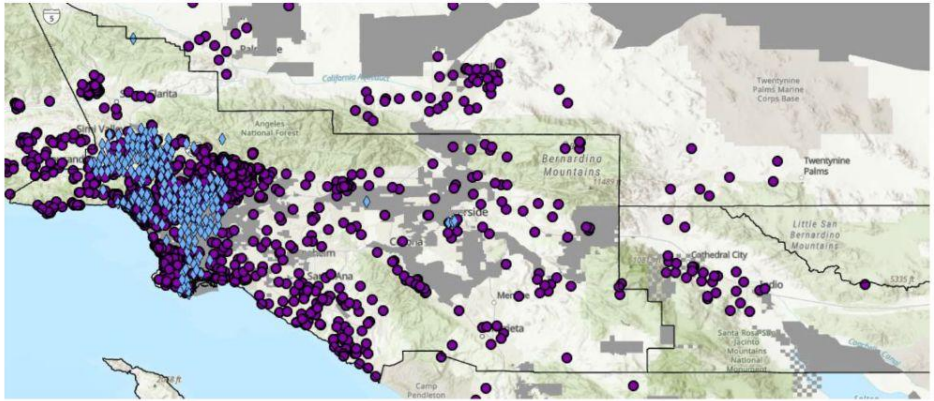
South Coast AQMD

Challenges with Using Sensors for Real-Time AQI:

Sensors are not equally distributed due to socioeconomic factors

- PurpleAir sensors more concentrated near the coast
- Clarity sensors mostly at LAUSD locations
- Unequal distribution was addressed by
  - targeted sensor deployments by the AQ-SPEC program
  - modifying the “neighborhood” size in real-time AQI map

PurpleAir and Clarity sensors are much more widely deployed in coastal areas and Los Angeles County



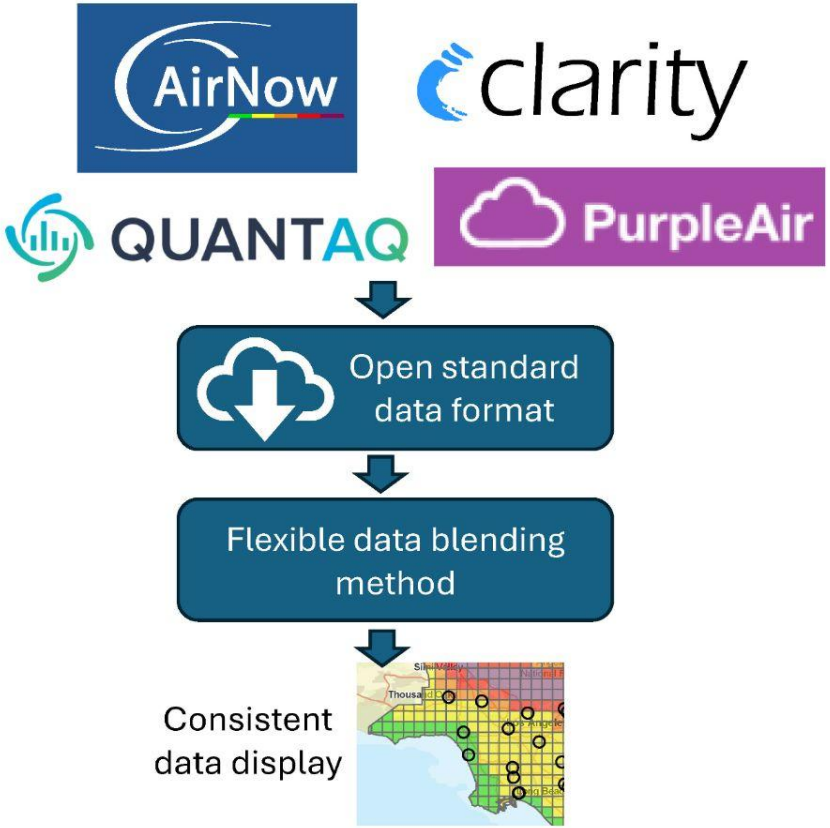
SB 535: Disadvantaged communities

South Coast AQMD

Challenges with Using Sensors for Real-Time AQI:

Integrating new sensors and data providers into real-time AQI products is time consuming

- Could be improved by implementing an open standard data format so that code changes are minimized
  - NetCDF is one example of open standard that may be useful
- A flexible data blending method as used for PM2.5/O3 in real-time AQI map helps to speed up integrating new data



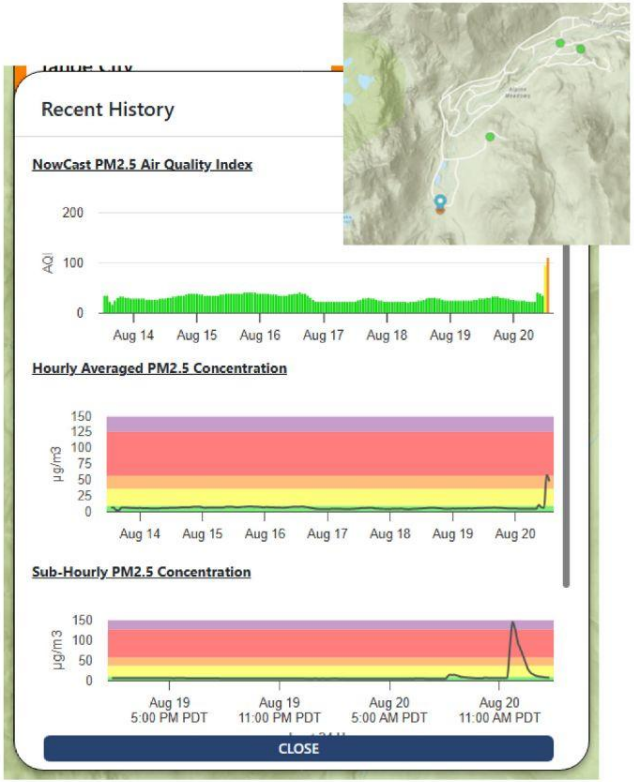
South Coast AQMD

Challenges with Using Sensors for Real-Time AQI:

Want responsive data display, but recommended actions require time averaging

- AQI is “slow” and “aggregated” since it relies on time averages (and neighborhood averages for AQMD real-time map)
- It is difficult to recommend actions to reduce exposure for shorter duration data and those recommendations are likely event-specific
- More frequent data updates may cause unnecessary actions or confusion by the public
- One way to increase responsiveness is to use moving windows to continuously update data

Example: short-duration, single-sensor spike



South Coast AQMD

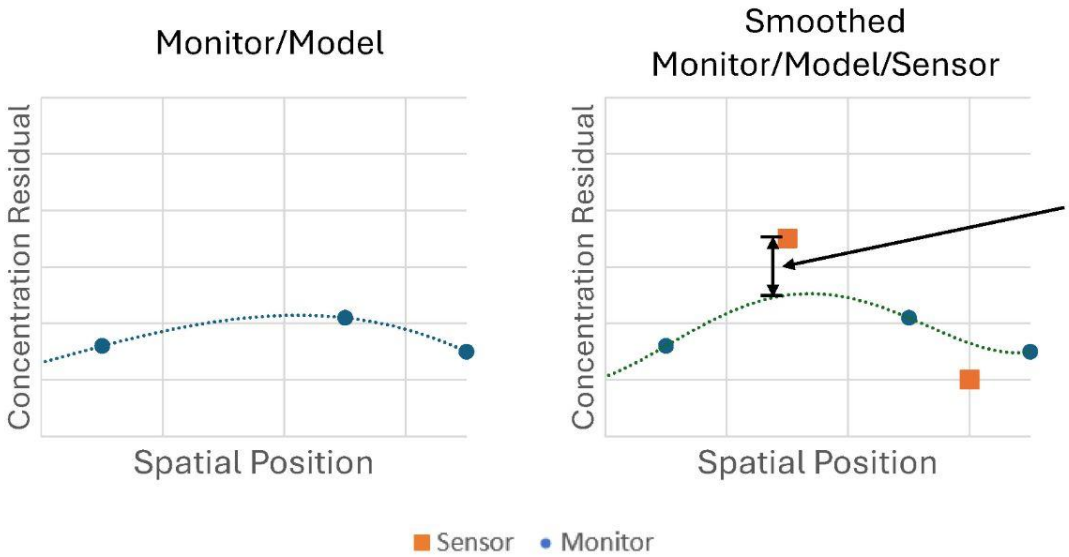
Conclusions

- The real-time AQI map improves interpolation accuracy and avoids user misinterpretation of monitor and sensor measurements
- Incorporation of Clarity Node-S PM2.5 sensor data into the real-time AQI map slightly reduces root mean square error and slightly increases mean bias at two locations with co-located regulatory monitors
- It is useful to incorporate additional sensor data if it doesn't degrade performance since this helps users interpret the data and may improve map performance in areas without regulatory monitors
- South Coast AQMD is integrating other sensors as they become available
  - Aeroqual AQY $PM_{2.5}$, PM_{10}, and O_3
  - QuantAQ sensors for PM2.5, PM10
- There are many challenges and opportunities for unique solutions for specific applications of sensor data

Supplemental Slides

South Coast AQMD

How the AQI Map Blends Monitor/Model/Sensor Data

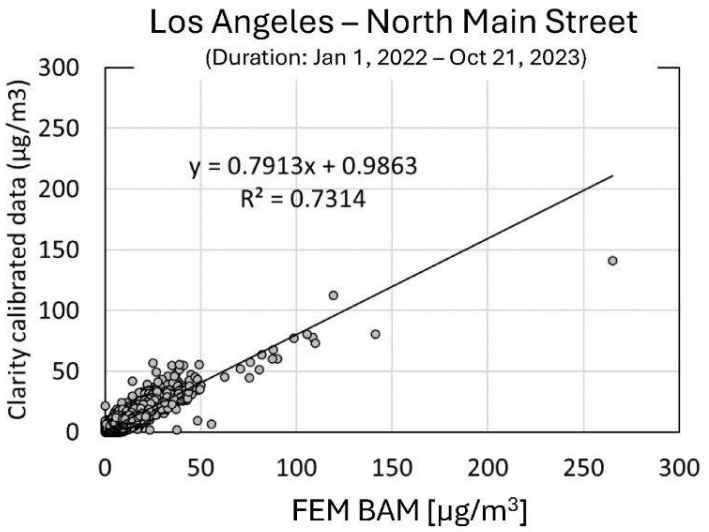


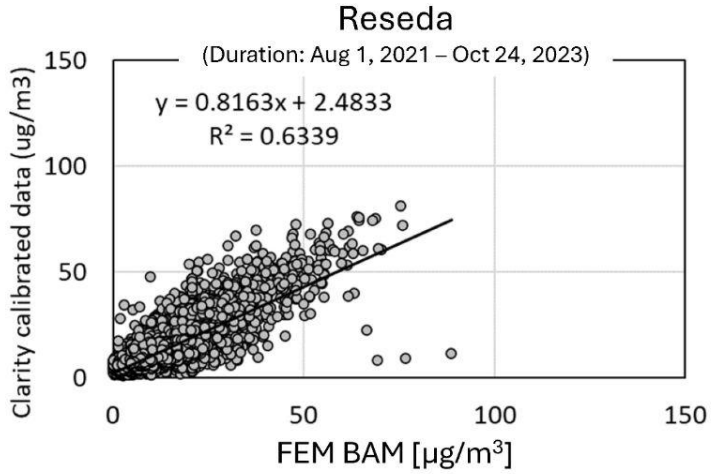
Concentration "surface" is fixed to regulatory monitors. Between monitors, model and consumer-grade sensor data modifies the concentration surface based on their relative uncertainties.

South Coast AQMD

Sensors were Evaluated Before Use in Real-Time AQI Map

- The South Coast AQMD AQ-SPEC Program evaluated the Clarity Node and found strong correlations with the FEM BAM in the field
- Good correlations were also observed between the Clarity Node and FEM BAM at the CELA and RESE sites
- Performance was not dependent on relative humidity or temperature

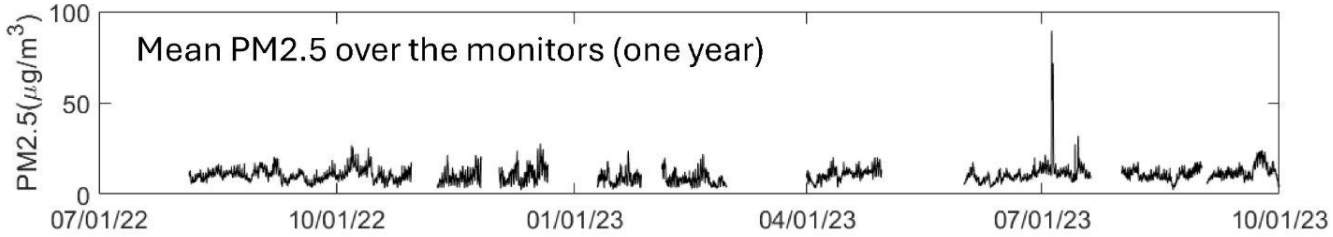




South Coast AQMD

Leave One Out Cross Validation Results

	With PurpleAir		Without PurpleAir	
	With Clarity	Without Clarity	With Clarity	Without Clarity
RMSE	5.20	5.22	5.25	5.58
Mean Bias	1.88	1.86	1.64	0.65
	PA + BAM + Clarity+ NOAA	PA + BAM+ NOAA	Clarity + BAM+ NOAA	Only BAM + NOAA



South Coast AQMD

Building Capacity of Vulnerable Communities in California's Fire Prone North Coast to Collect Air Quality Data and Access Solutions

Pepperw
PRES
Inspiring conservation thr

Partners:

-Universities Space Research Association

-Soluna Outreach Solutions & LatinX Hub

-Citizens Organized to Prepare for Emergencies

-Nuestra Comunidad

-North Bay Jobs with Justice

-Bay Area Environmental Research institute

-Northern Sonoma County Air Pollution Control District

-Sonoma Technology, Inc.

-Clarity Movement

Ryan Ferrell, Pepperwood Sentinel Site Manager

EPA

Goals and Gains

- Provide the North Bay community with accurate, reliable and real time air quality data
- Empower community members to make data informed decisions about their exposure levels to wildfire smoke and other sources of PM 2.5

The Community

- ~500,000 people live in Sonoma County
- Nearly half reside in the 101 corridor from Santa Rosa to Cloverdale through our project area in the Alexander Valley.

Key concerns:

-Wildfire Smoke

-Health

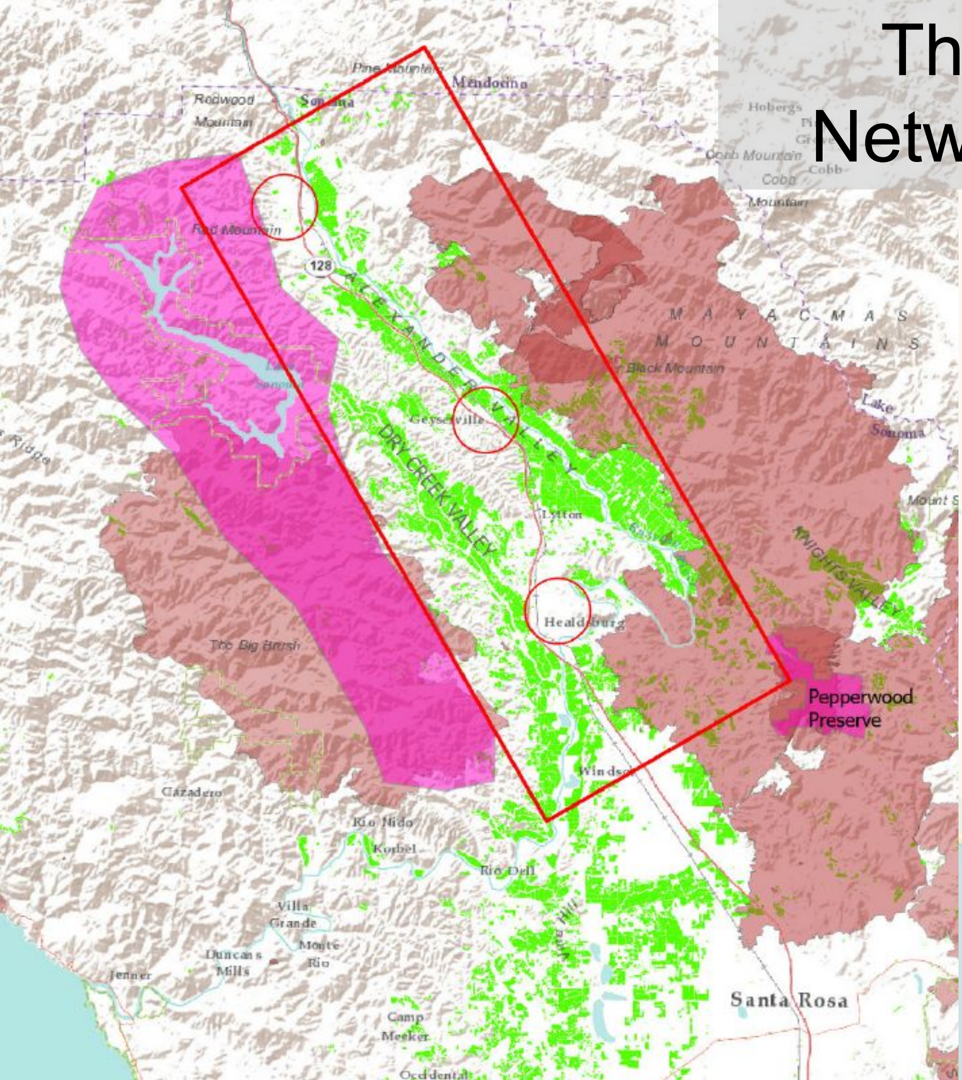
-Family

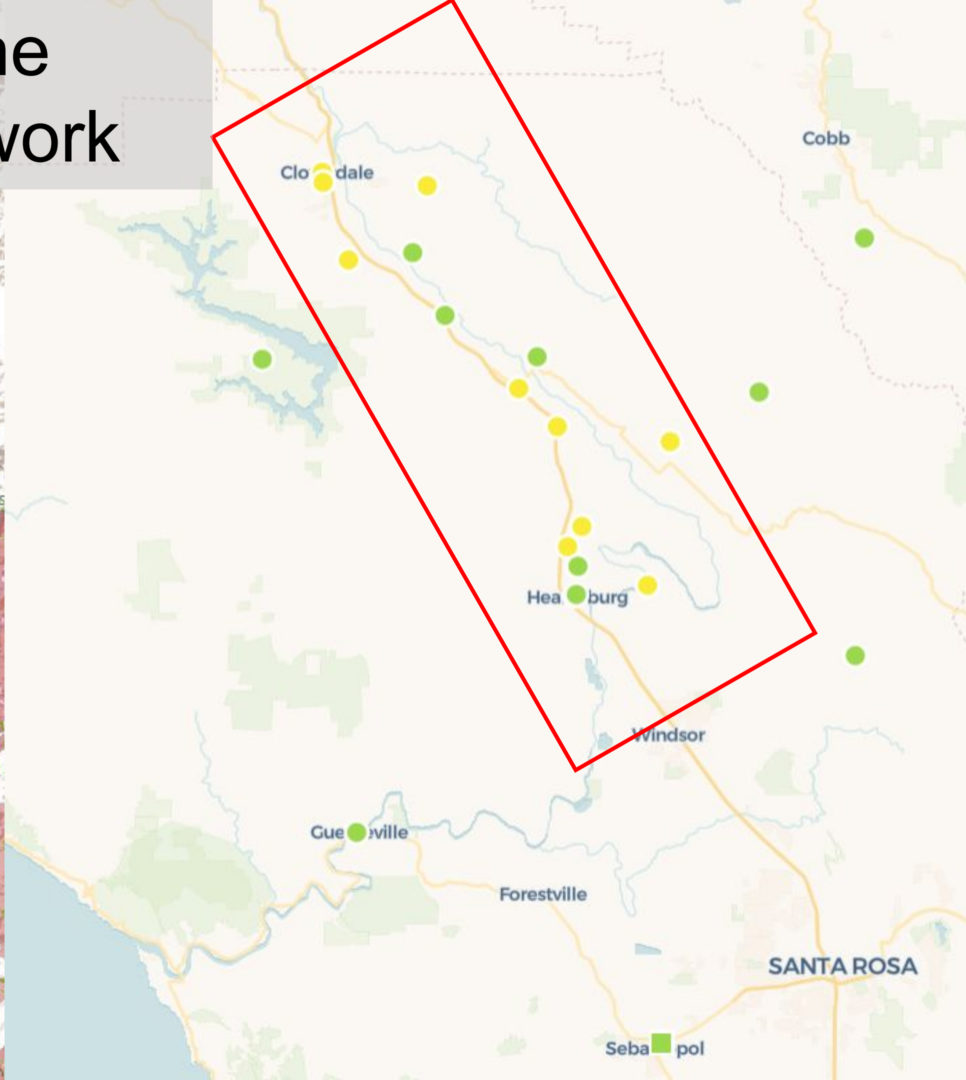
-Work

-Event response

Latino participants in Cloverdale, Windsor, and Geyserville shared that poor air quality is an unavoidable part of their environment, with limited access to protective equipment, limited knowledge of the Air Quality Index, and little formal guidance on how to stay safe

The Network


Pine Mountain
Mendocino
Redwood Mountain
Sonoma
Red Mountain
128
ALEXANDER VALLEY
MAYACMAS MOUNTAINS
Black Mountain
Lake Sonoma
Geyserville
DRY CREEK VALLEY
Lytton
Healdsburg
KNIGHTS VALLEY
Pepperwood Preserve
The Big Brush
Cazadero
Windsor
Rio Nido
Korbel
Rio Dell
Villa Grande
Monte Rio
Duncans Mills
Jenner
Camp Meeker
Occidental
Santa Rosa
Hobergs
Cobb Mountain
Cobb


Cobb
Windsor
Forestville
SANTA ROSA

Regional Smoke Destination

- Northern Sierran smoke flows through the Bay Area
- Local smoke sources pool in interior valleys

Just in time for the School year

Alexander Valley August 22nd, 2025 Pickett Fire

Thank you!

Thank you!

Questions?

Moderator

Sean Wihera

VP, Business Development & Partnerships

Clarity Movement

Levi Stanton

Solutions Engineering Lead

Clarity Movement

Carlos Torres

Director, OEHS

Los Angeles Unified School District (LAUSD)

Scott Epstein

Planning & Rules Manager

South Coast AQMD

Ryan Ferrell, MS

Sentinel Site Manager

Pepperwood Preserve