

A multi-pollutant fusion system

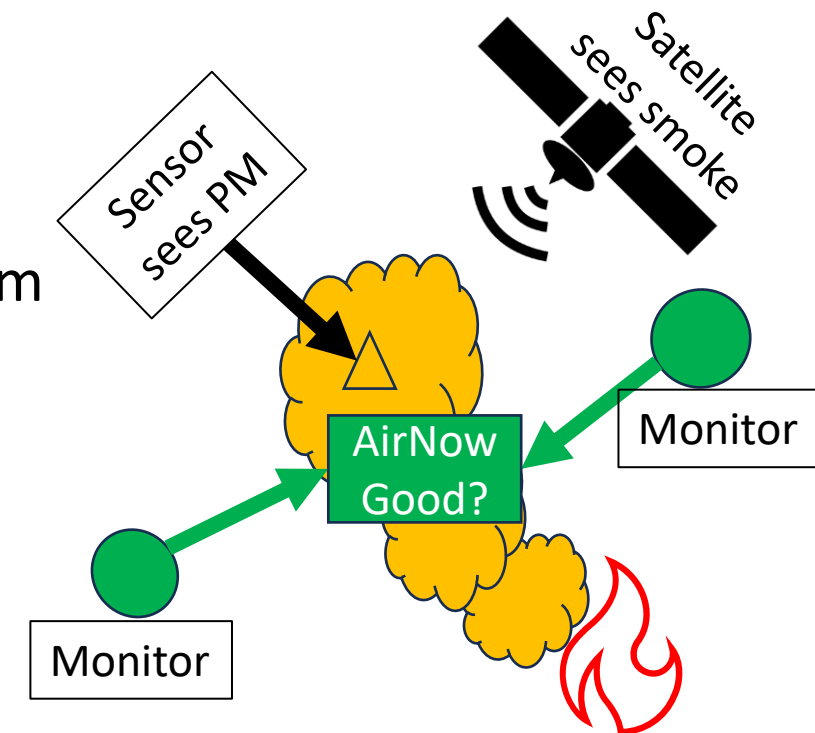
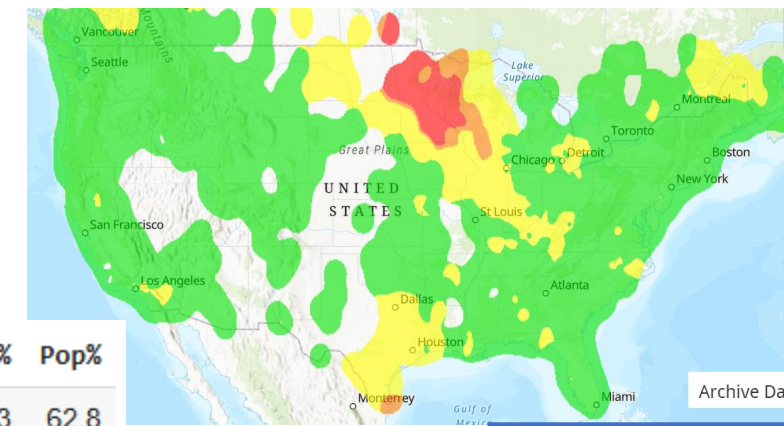
*Disclaimer: The views expressed in this presentation are those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.*



# AirNow Vision: ultra-high-resolution data for all Americans!

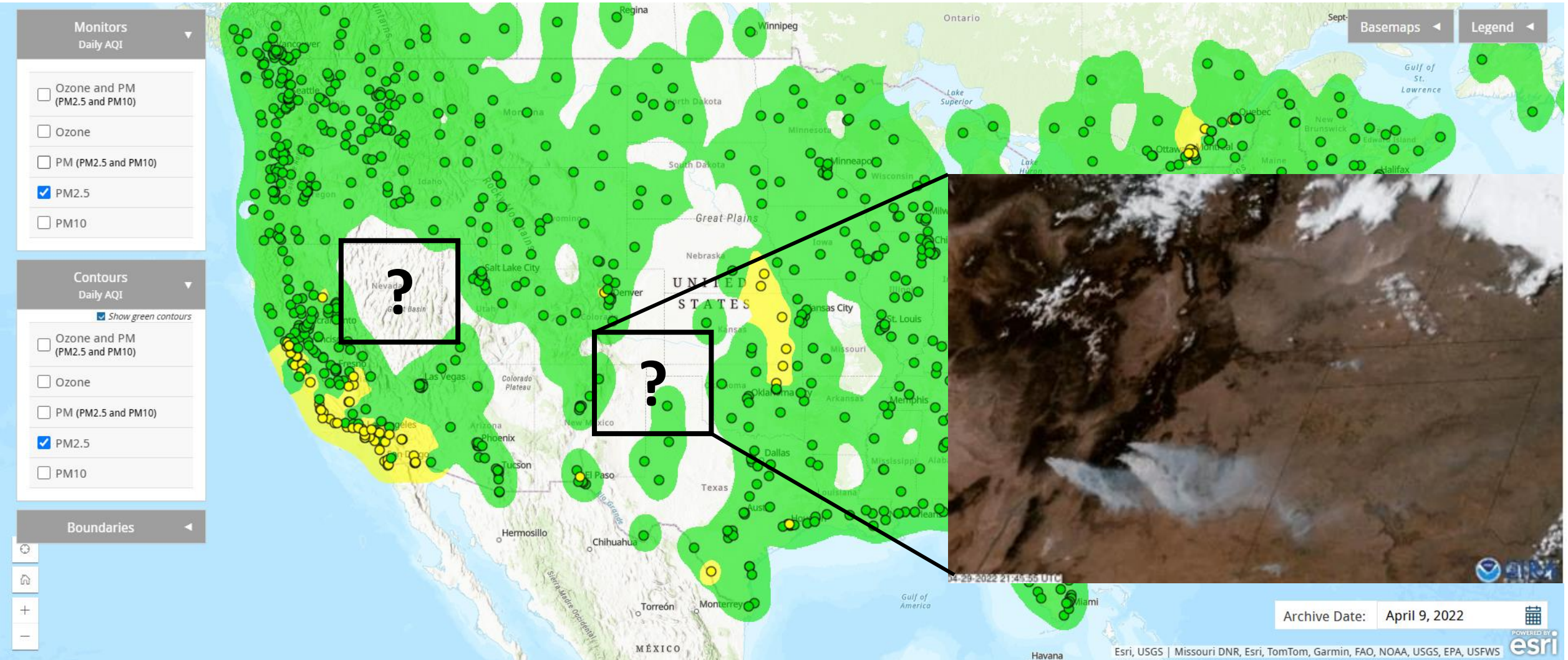
- Currently using just monitors.
  - <30% of 3224 US counties
  - <80% population
  - Ignoring satellites and sensors
- Example Problems
  - Smoke plumes go between “good” monitors.
  - AQI might be based on ozone where PM is the problem
- Data Fusion can:
  - Bring additional sources of data (sensors, satellites)
  - Increase reasonability of monitor interpolation
  - Allow for multi-pollutant AQI more places

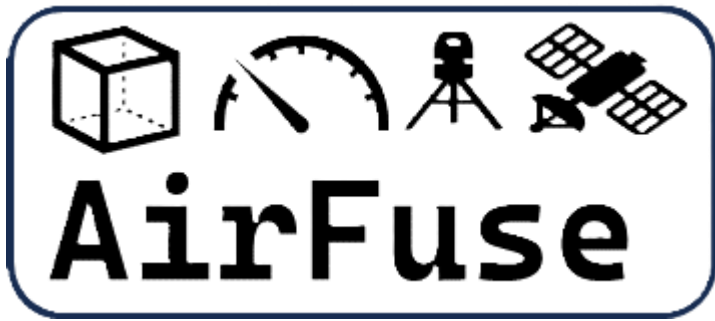
*	Pop [M]	County%	Pop%
Ozone and PM25	210.8	15.3	62.8
Ozone Only	26.7	7.3	8.0
PM25 Only	24.9	6.1	7.4
Neither	73.1	71.3	21.8



\*County/Population from July 2024

# HAQAST Showcase Example





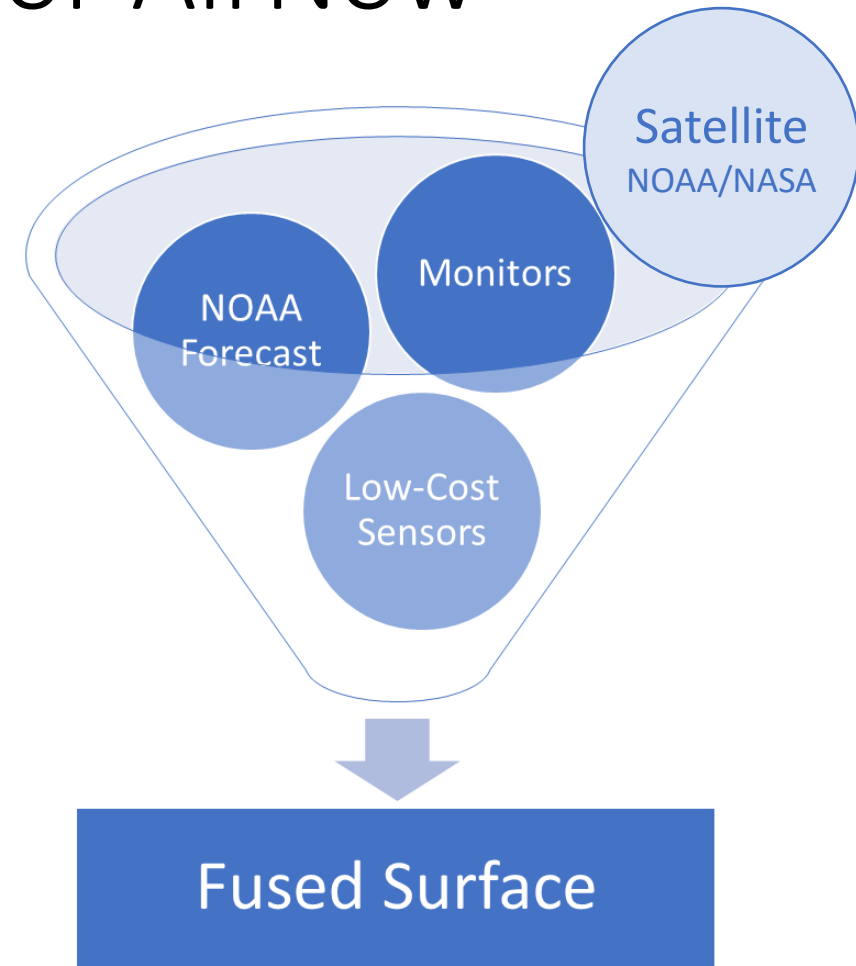
# Realtime hourly maps of PM<sub>2.5</sub> and ozone for AirNow

## Best available data sources

- AirNow monitors (~1000 per hour)
- PurpleAir sensors (~9k per hour)
- Near-real-time satellite observations (1.4M)
  - GOES-PM25 developed by NOAA/NESDIS/STAR
  - NASA HAQAST project connecting AirNow to NOAA geostationary satellite data
- NOAA Forecast w/bias correction

## Current Species Capabilities:

- PM2.5
- Ozone too (no PurpleAir or satellite).
- PM10 – not yet.



Available on [airnowtech.org](http://airnowtech.org) since March 2024



# AirFuse

## timeline

- Data Fusion Goals:**
- NOAA Satellite to AirNow
  - Chet asks for PurpleAir
  - Project published EM Sept

- Pilot on AirNowTech:**
- 1-hr Ozone; 1-hr PM25
  - Every hour publicly available

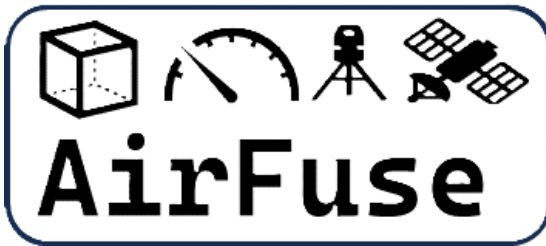
[Talking w/ Google, NASA, STI, AWMA, ...]



- NASA/NOAA/EPA Collaboration:**
- OAQPS/OID/ORD
  - “Incorporating Satellite Data Updates into AirNow”

- Validation Project:**
- 1-year 10-fold cross validation
  - 7 method comparisons
  - OAQPS intern
  - Method Selection: feasibility, performance, stakeholder constraints

- Ongoing Application:**
- 1-year+ live on AirNowTech
  - Collecting feedback from states
  - Preparing for Fire & Smoke Map



# data sources



## AirNow

- Collaborate: AirNow Team
- Scope
  - Hourly or AQI-metric
  - US, Canada, Mexico



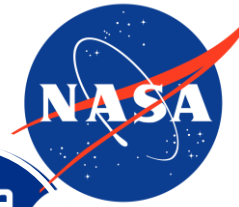
## PurpleAir

- EPA Agreement
- Using 5-step Barkjohn 2021 correction and QA
- Scope
  - Hourly (FASM has AQI-metric)
  - Global



## GOES-PM25

- Collaborator: NOAA-NESDIS
- Feed: GWR PM25 [https \(STAR to OSPO\)](https://STAR.to.OSPO)
- Scope
  - Hourly (only daylight)
  - Continental US (~3km)



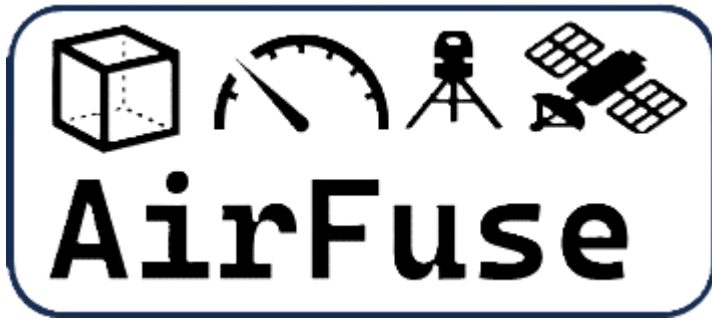
## CMAQ

- Collaborator NOAA-NWS
- Feed: AWS, [https](https://)
- Scope:
  - US, Canada
  - 5.079km (from 13km)
  - Hourly or AQI-metric

Optional

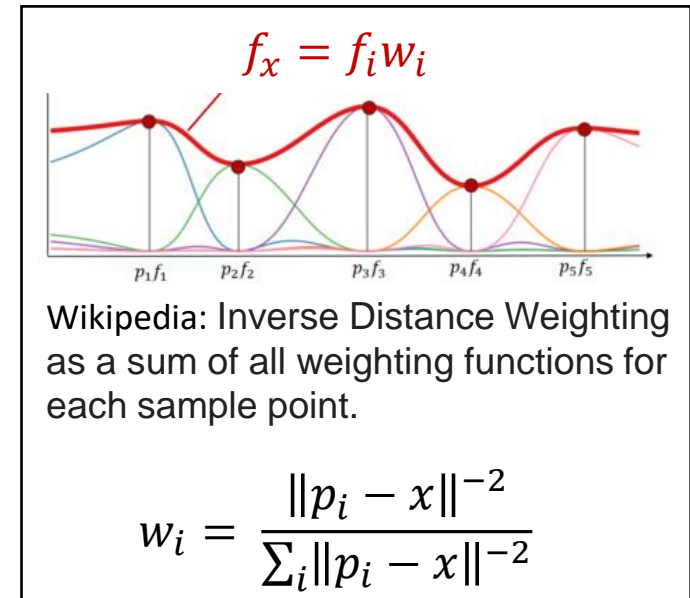
Or GMAO  
GEOS-CF





# Fusion Methods

1. Acquire forecast model ( $y$ )
2. Acquire observations ( $o$ ): monitors, sensors, and satellite
3. Calculate model bias on grid
  - First at obs points ( $b_i = y_i - o_i$ )
  - Select neighbors ( $i$ ) via Delaunay Diagram (faster w/ nearest)
  - Interpolate bias from points to grid ( $b_x = \sum_i w_i b_i$ )
  - Weight monitors more than PurpleAir (0.25x)
4. Subtract gridded bias ( $f_x = y_x - b_x$ )
5. Measure Success
  - 10-fold cross validation (withhold 10%; predict withheld; repeat)
  - Never perfect... usually better than AirNow's interpolation =

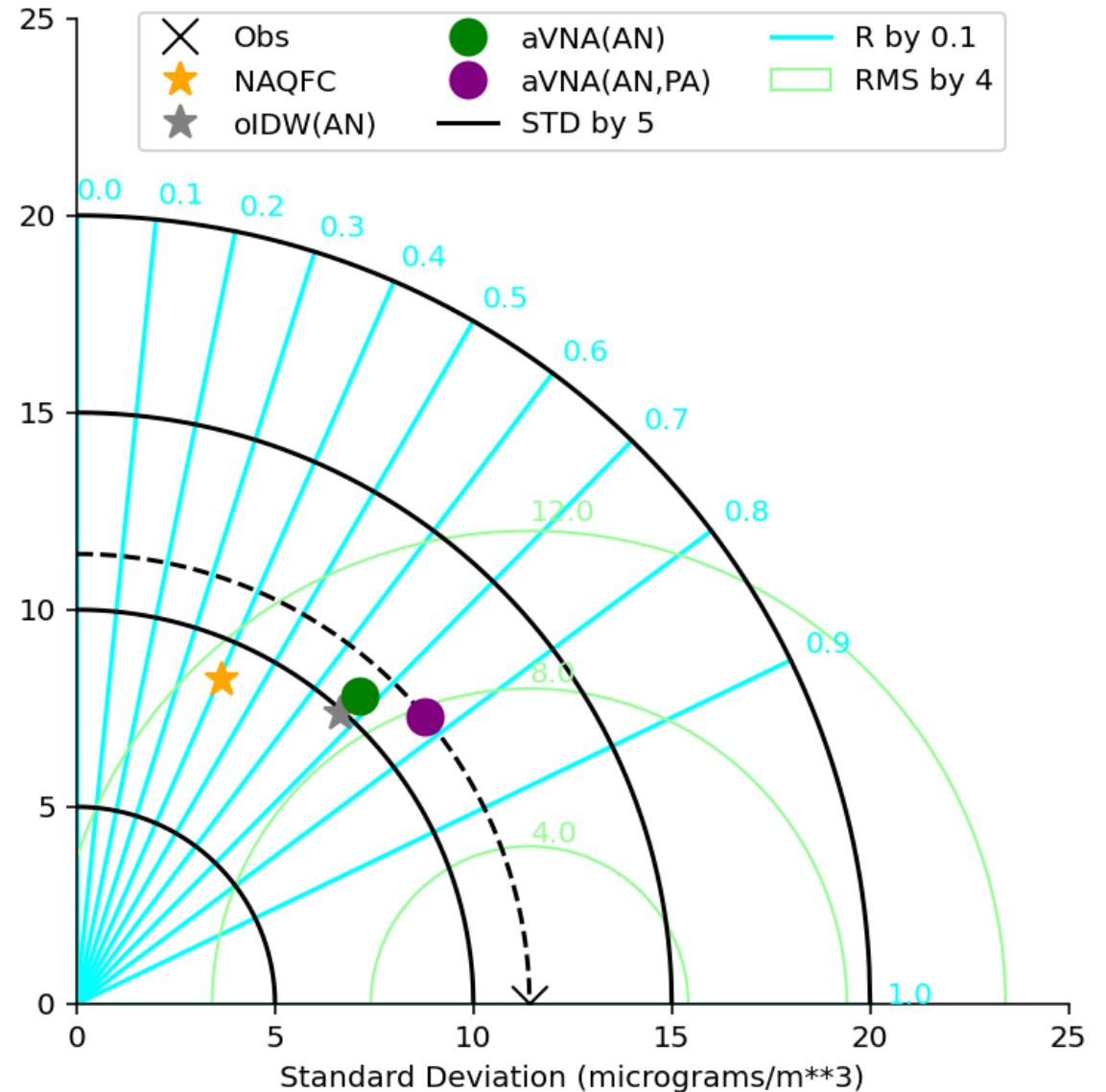


$$\sum_{i=1}^{10} \frac{\|p_i - x\|^{-5}}{\sum_j \|p_j - x\|^{-5}} o_i$$

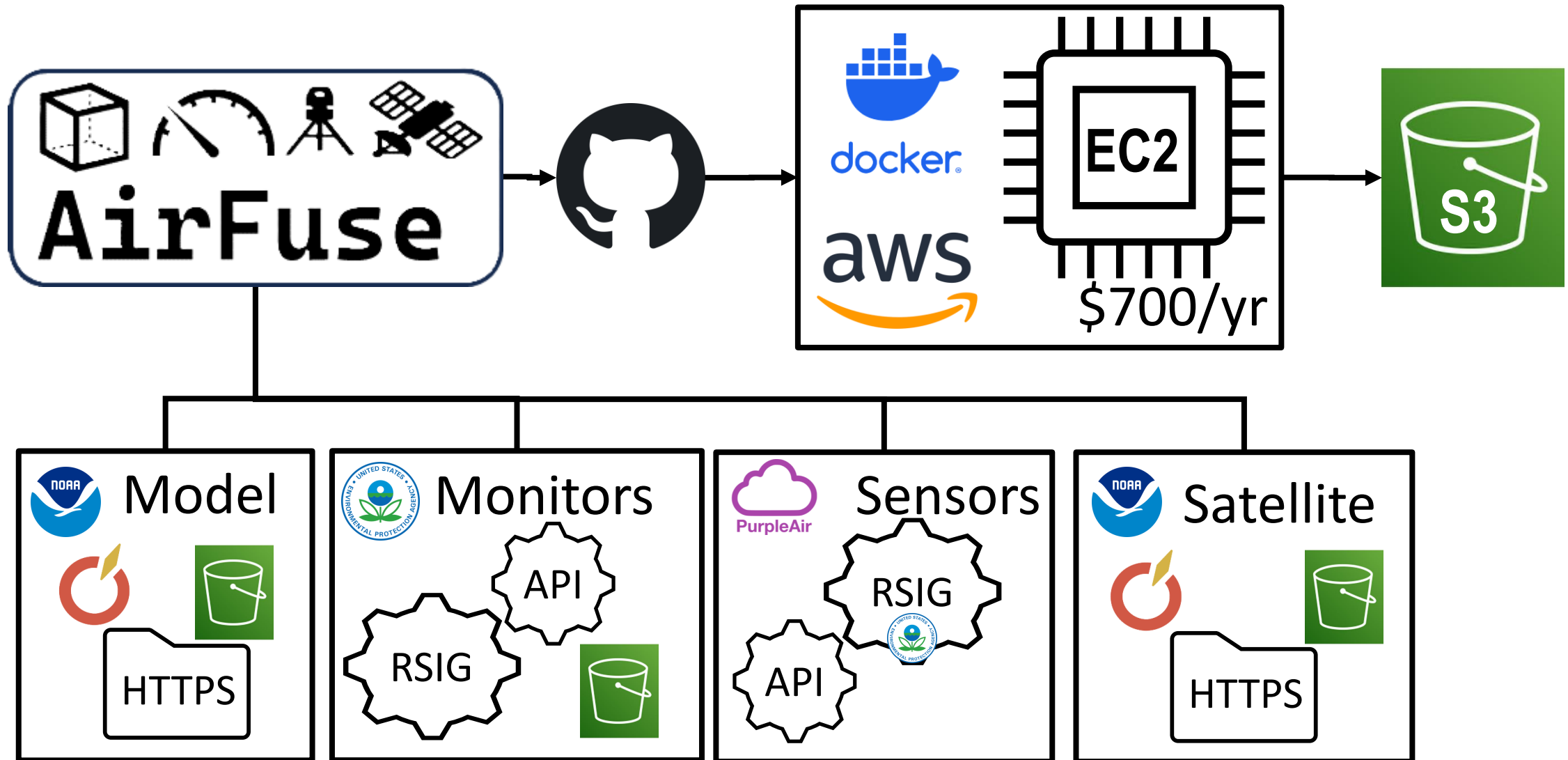
\*interpolating bias is like eVNA, but additive

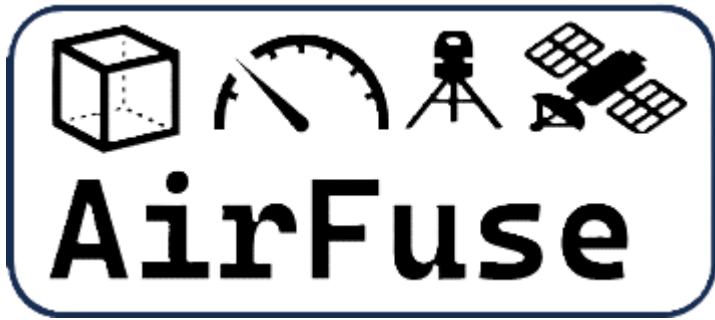
## Performance Summary: June 2021-June 2022 (All hours; n=8M)

- Multiple statistics matter
  - Pearson correlation (y-axis)
  - centered Root Mean Squared Error (x-axis)
  - Reproduction of standard deviation
- The **NAQFC** has the lowest correlation, the highest RMSE, and the worst standard deviation.
- The **AirNow** and interpolation (oIDW) have similar correlation, **AirNow** has better standard deviation.
- The fusion with **PurpleAir** improves standard deviation, correlation, and root mean squared error.
- Is the story more complex? When does one fail and the other succeeds?



# AirFuse runs in the cloud (or locally)

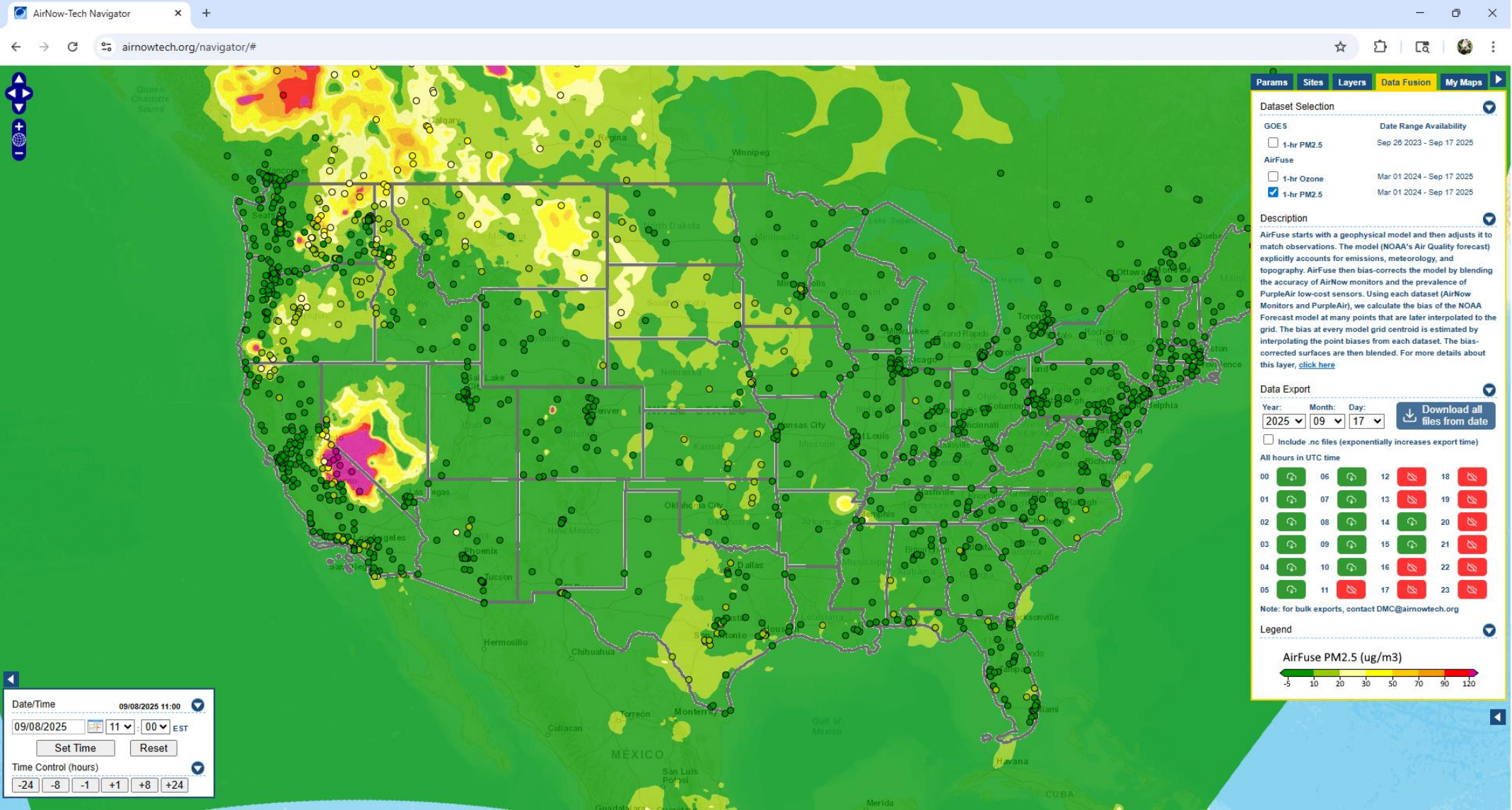


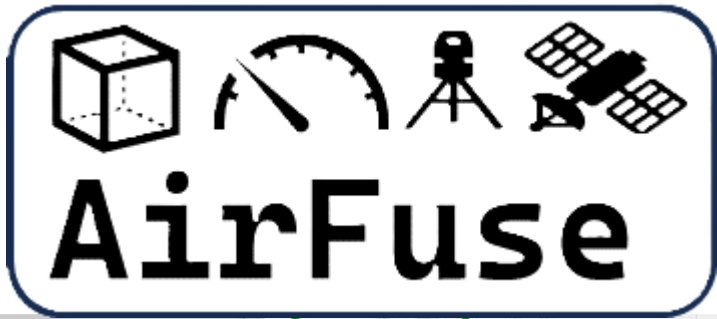


## Pilot: Nuts and Bolts

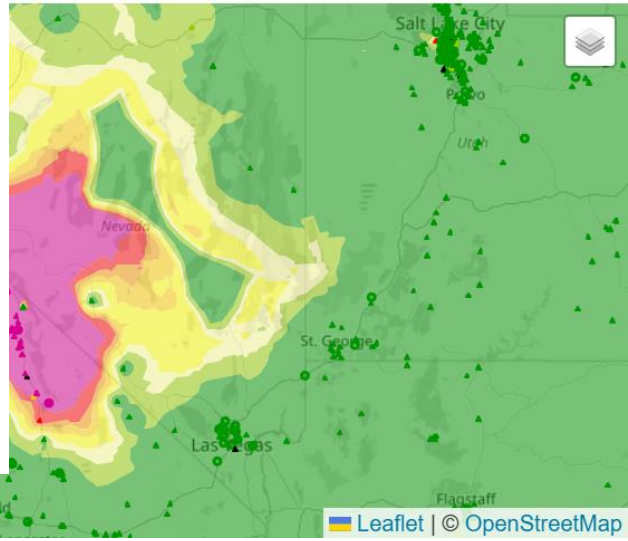
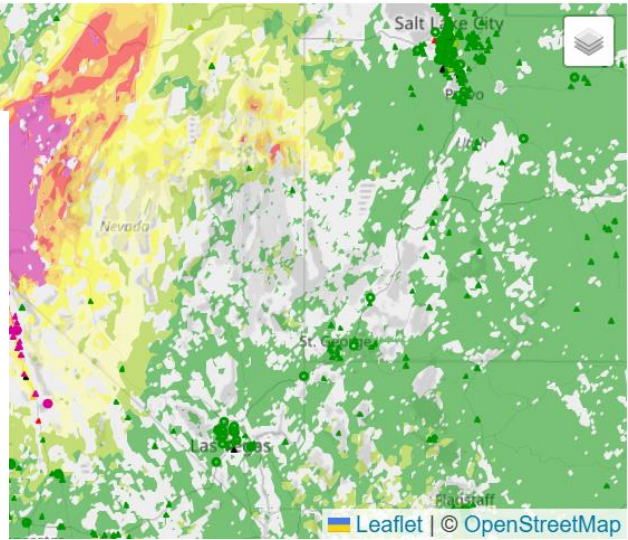
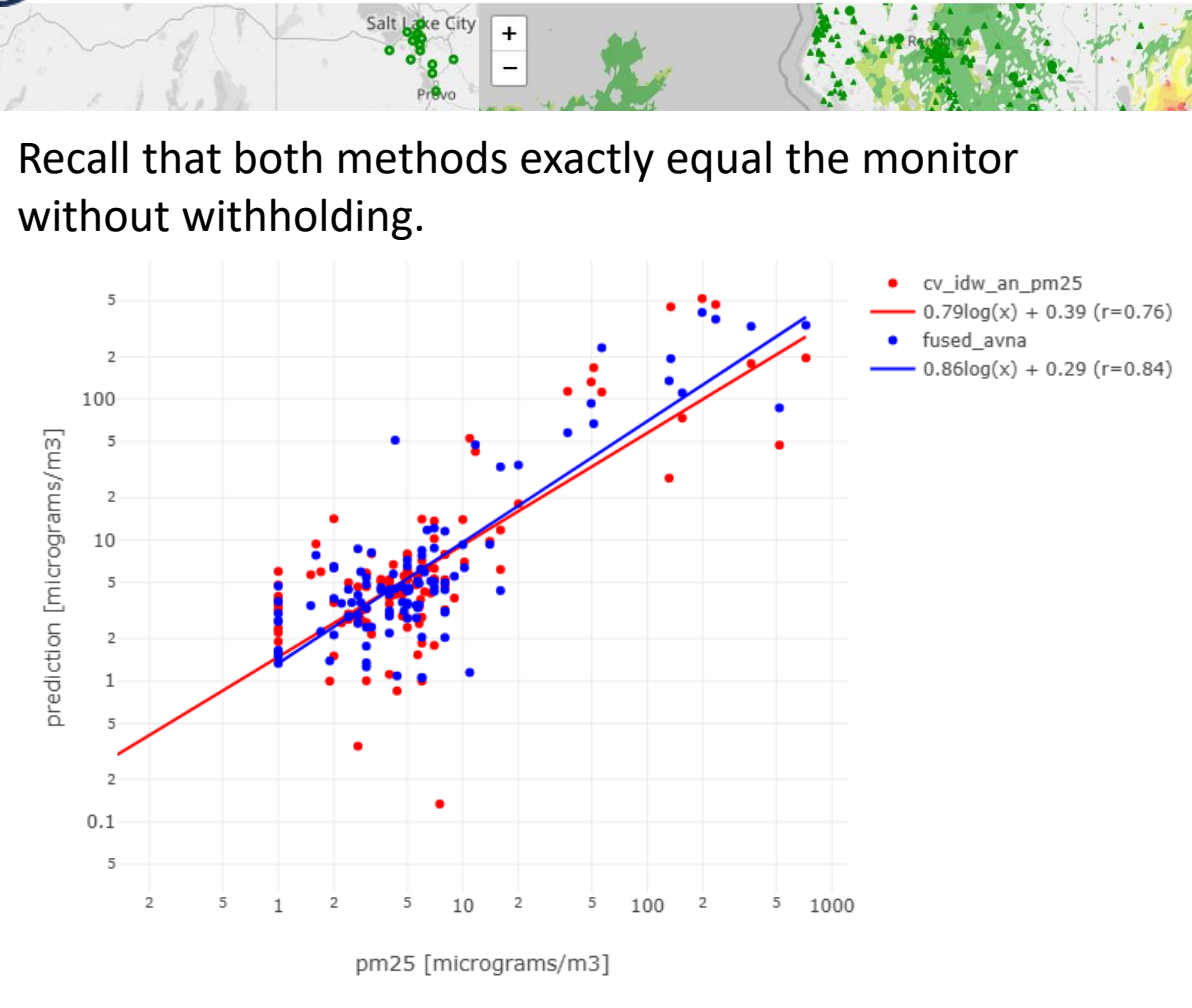
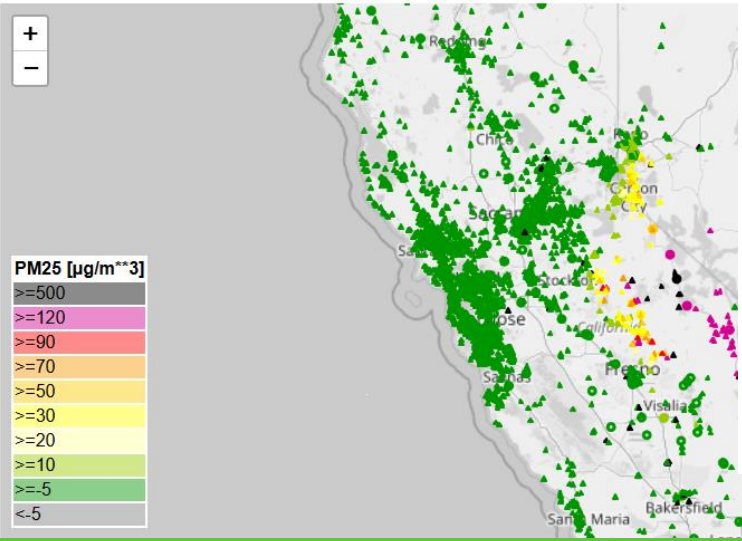
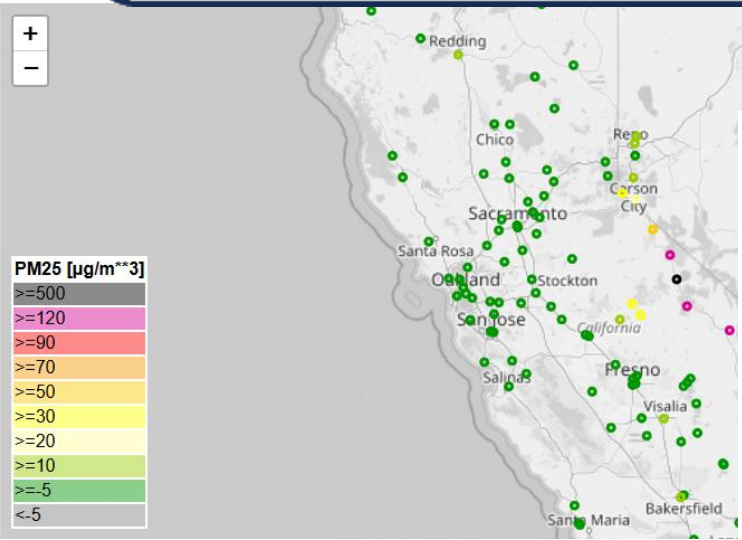
- Currently run 1/hr at 55min past the hour.
  - **Most** observations have been reported.
  - Regular AirNow interpolation currently happens more frequently
  - Observations updated 25min and 55min past the hour for 2days
- Runs on AWS ec2 w/ 16 vCPU for about 3min (ozone and PM25)
  - Linearly-scaling parallelization, so time or CPU – approximate tradeoff
  - \$0.08/hour - \$0.03/ozone-surface, \$0.05/pm25-surface
  - $\$0.08/h \times 24h/d \times 365d/yr = \$700/yr$
- Repeat runs (more data) would increase costs (2x=\$1400; 3x=\$2100)
- Let's look at some surfaces!

# AirNowTech - Sept 8 11EST

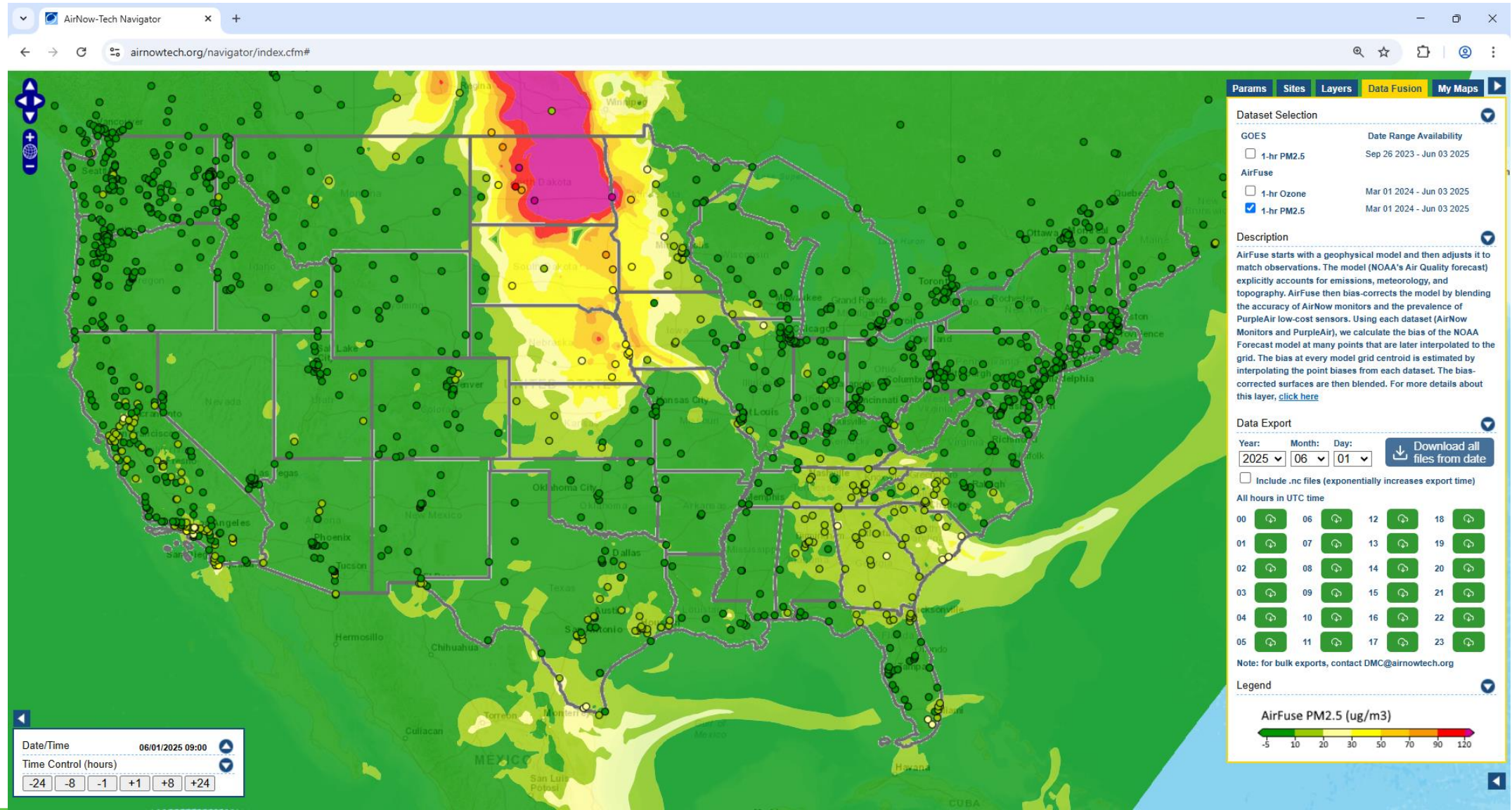


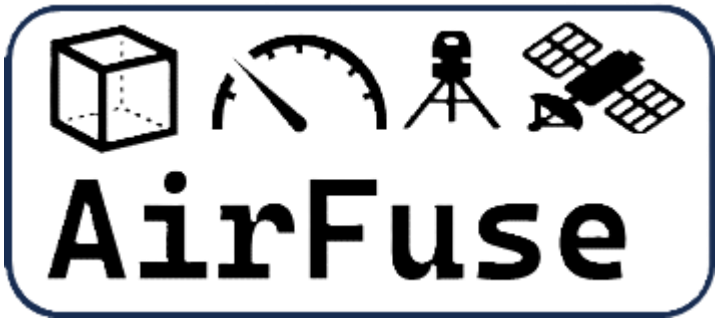


# Explained - Sept 8 11EST

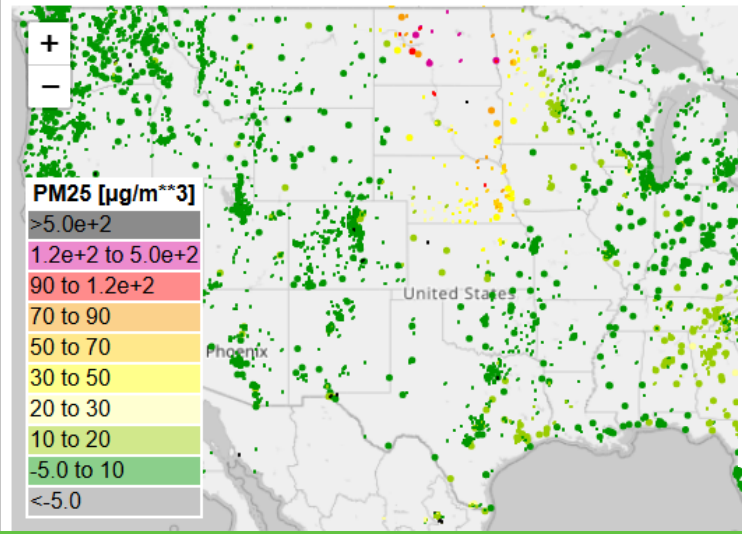
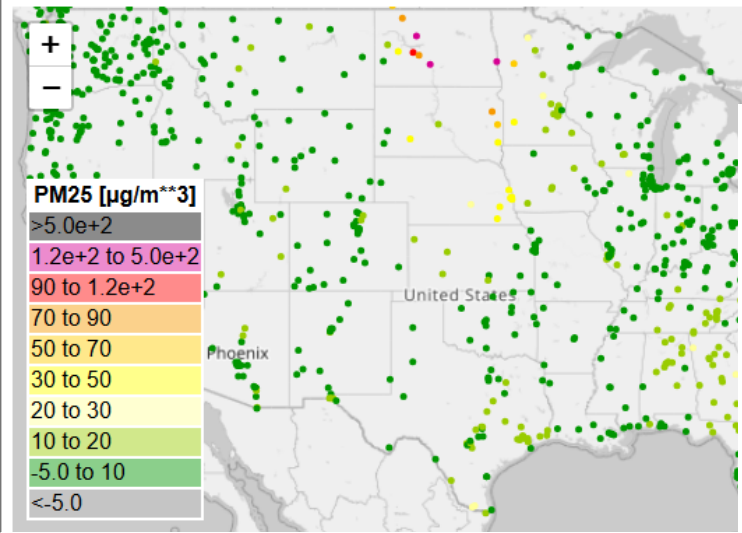


# AirNowTech - June 1 09EST

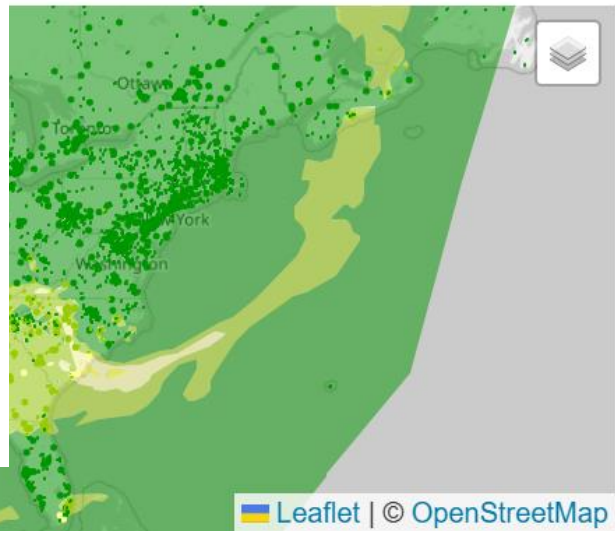
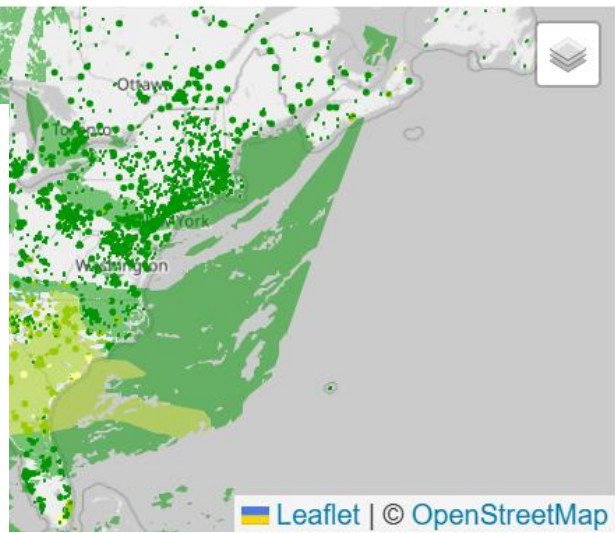
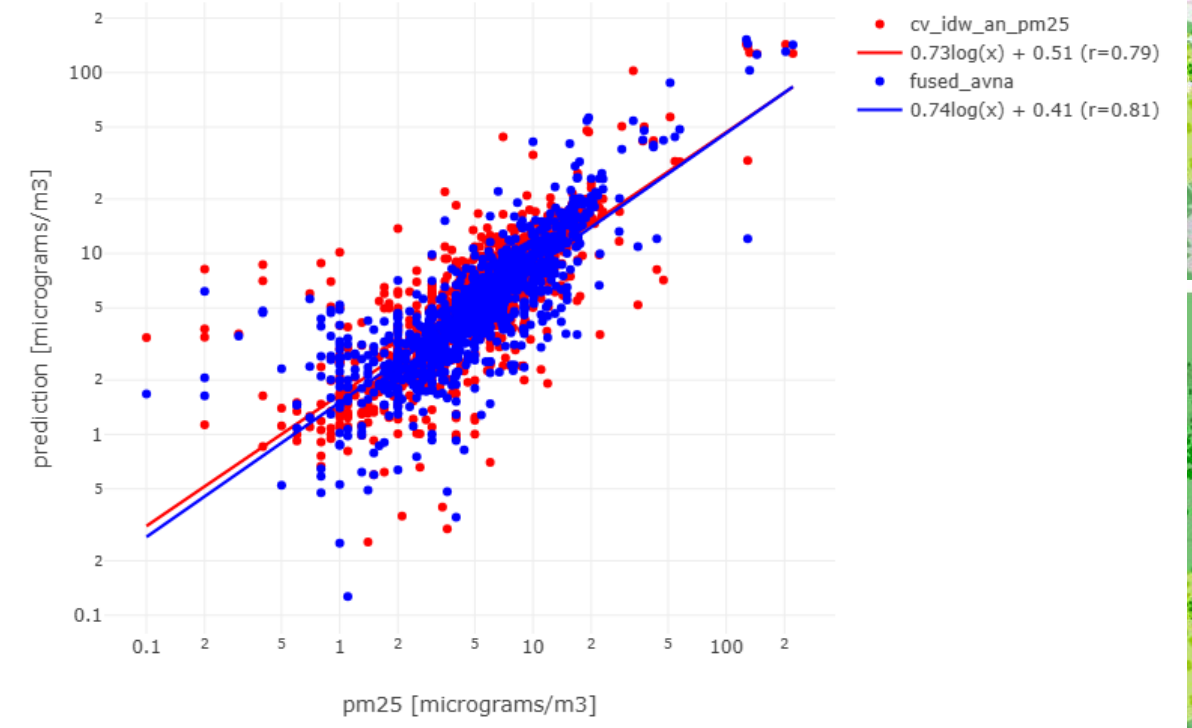




# Explained - June 1 09EST



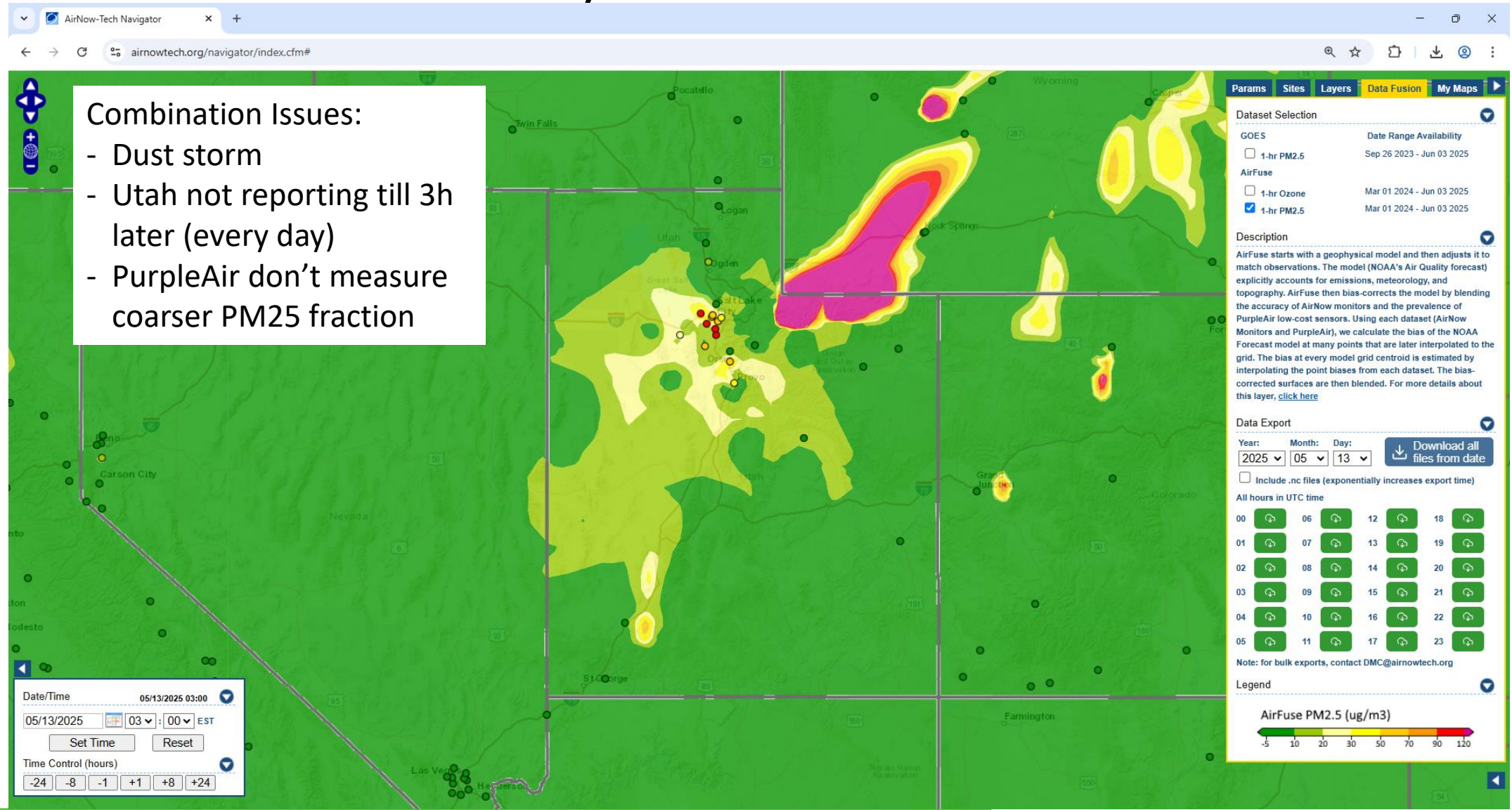
Recall that both methods exactly equal the monitor without withholding.

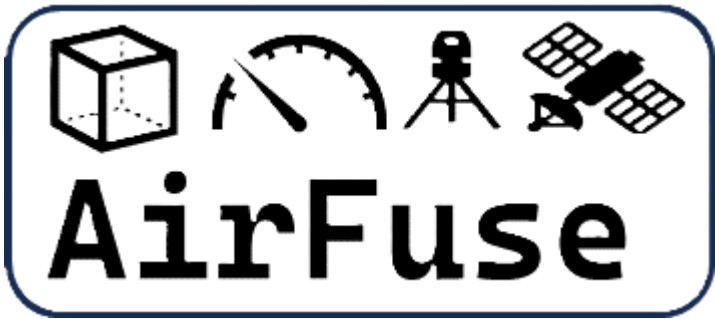


# AirNowTech May 14 – 03EST

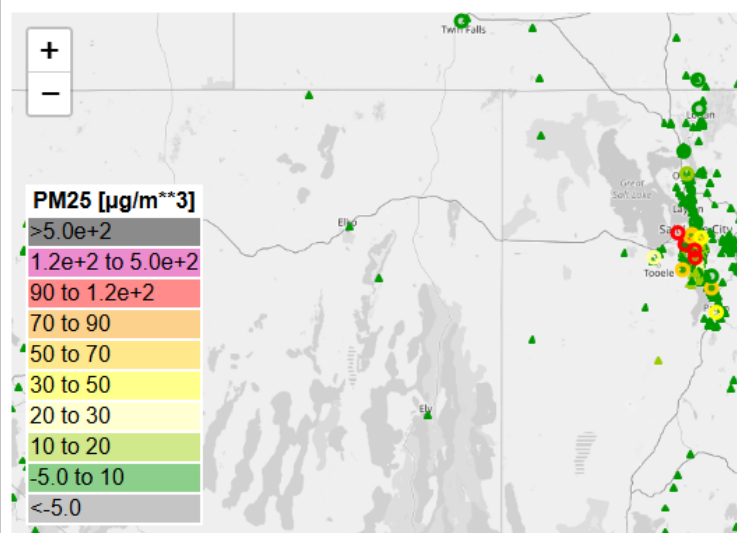
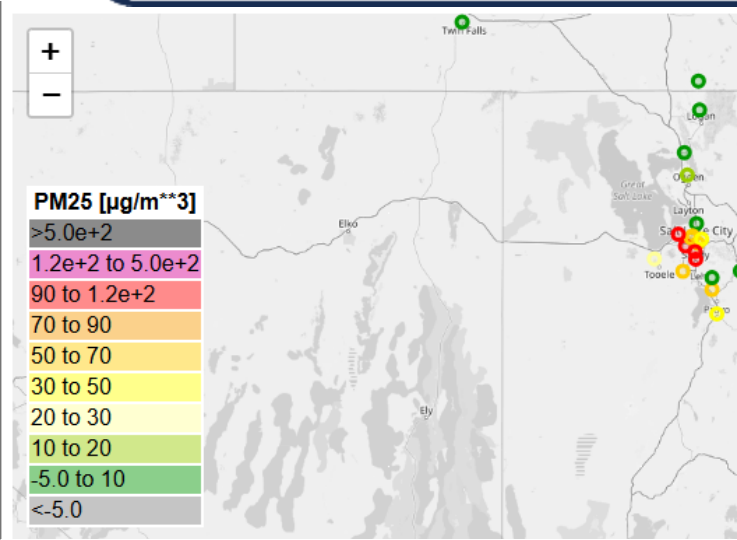
Combination Issues:

- Dust storm
- Utah not reporting till 3h later (every day)
- PurpleAir don't measure coarser PM25 fraction

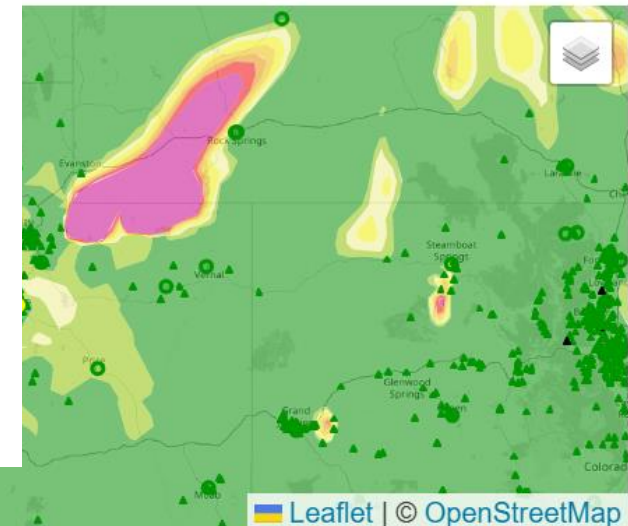
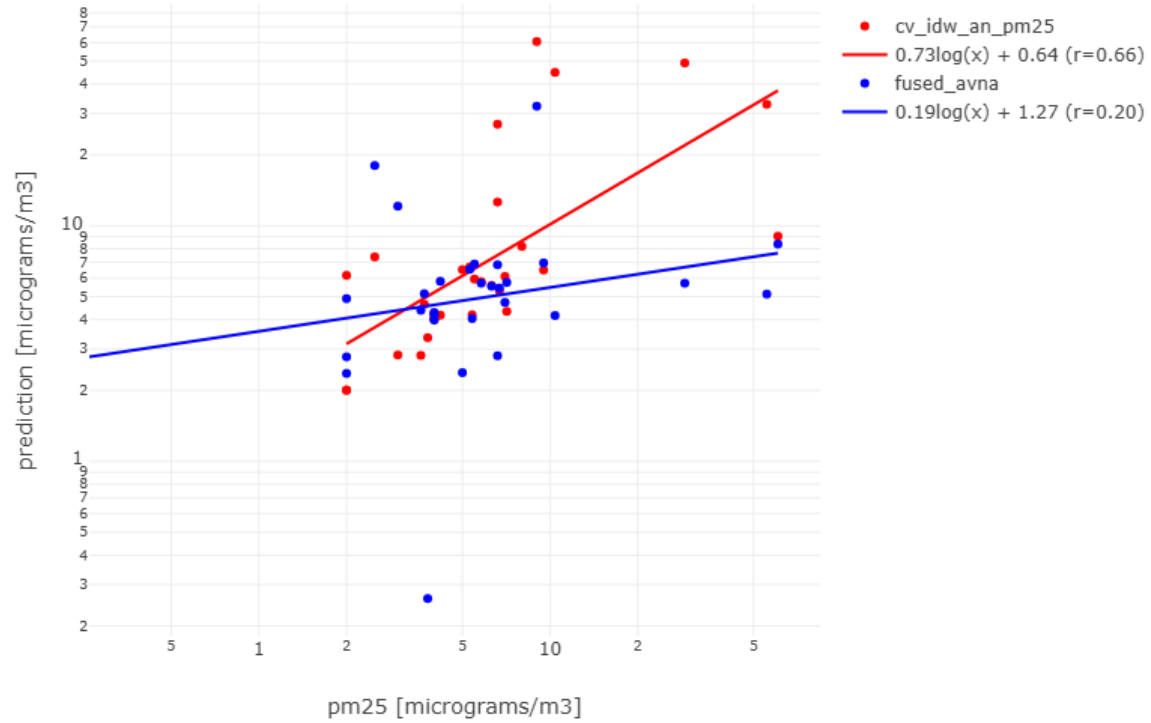




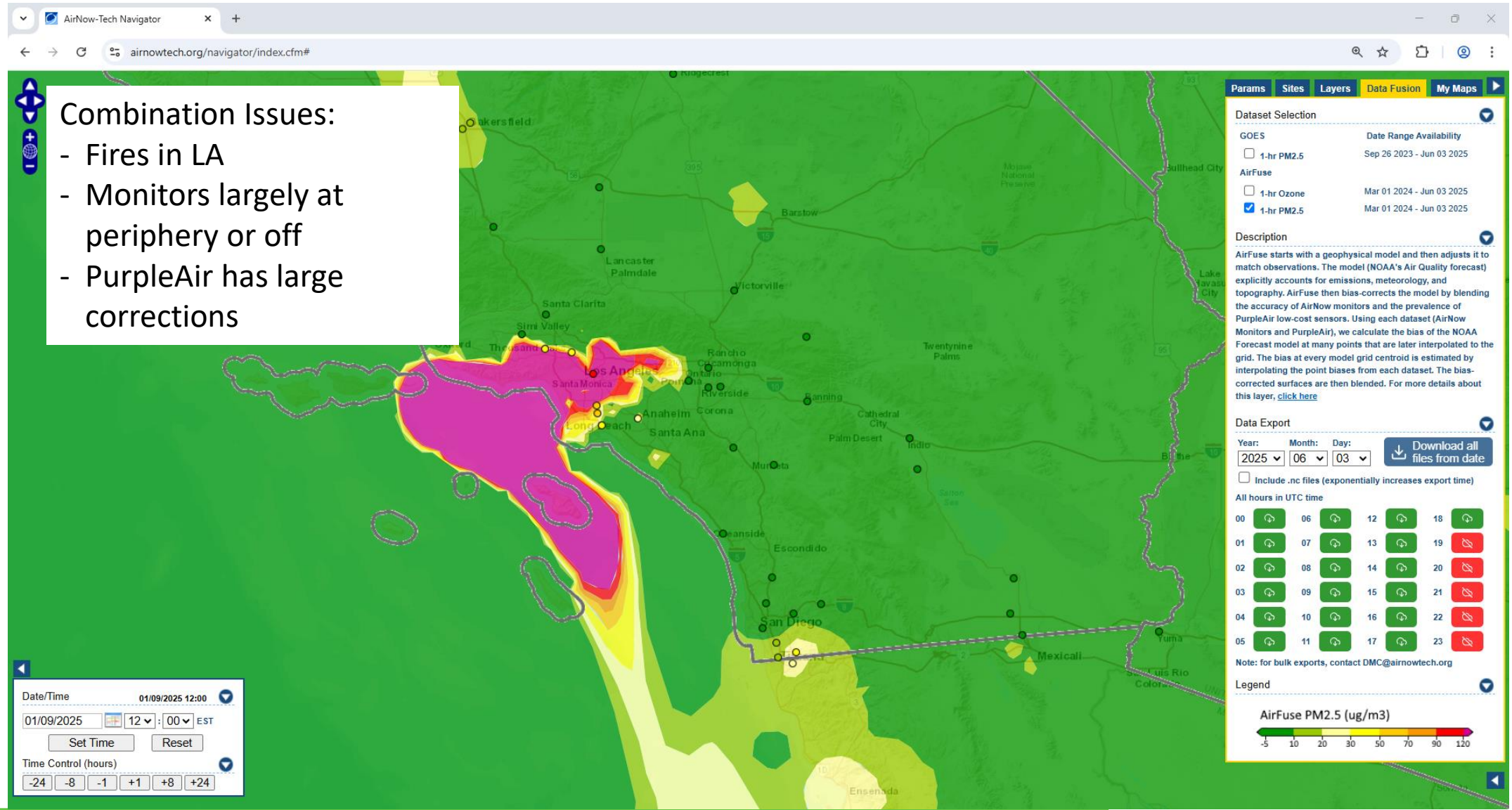
# Explained - May 14 04EST



Recall that both methods exactly equal the monitor without withholding. (fix from Sarah improves this!)



# AirNowTech Jan 09 – 12EST



**Combination Issues:**

- Fires in LA
- Monitors largely at periphery or off
- PurpleAir has large corrections

**Params Sites Layers Data Fusion My Maps**

**Dataset Selection**

GOES Date Range Availability

1-hr PM2.5 Sep 26 2023 - Jun 03 2025

**AirFuse**

1-hr Ozone Mar 01 2024 - Jun 03 2025

1-hr PM2.5 Mar 01 2024 - Jun 03 2025

**Description**

AirFuse starts with a geophysical model and then adjusts it to match observations. The model (NOAA's Air Quality forecast) explicitly accounts for emissions, meteorology, and topography. AirFuse then bias-corrects the model by blending the accuracy of AirNow monitors and the prevalence of PurpleAir low-cost sensors. Using each dataset (AirNow Monitors and PurpleAir), we calculate the bias of the NOAA Forecast model at many points that are later interpolated to the grid. The bias at every model grid centroid is estimated by interpolating the point biases from each dataset. The bias-corrected surfaces are then blended. For more details about this layer, [click here](#)

**Data Export**

Year: 2025 Month: 06 Day: 03 [Download all files from date](#)

Include .nc files (exponentially increases export time)

All hours in UTC time

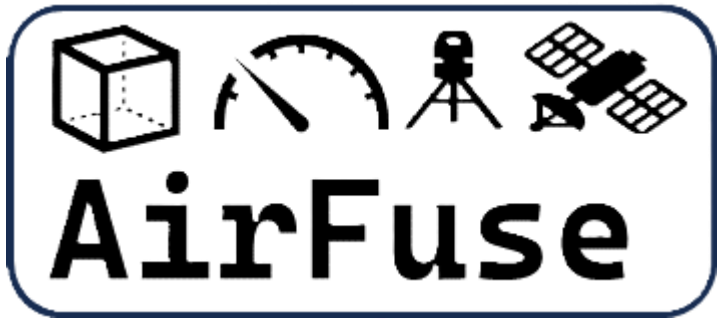
00	06	12	18
01	07	13	19
02	08	14	20
03	09	15	21
04	10	16	22
05	11	17	23

Note: for bulk exports, contact [DMC@airnowtech.org](mailto:DMC@airnowtech.org)

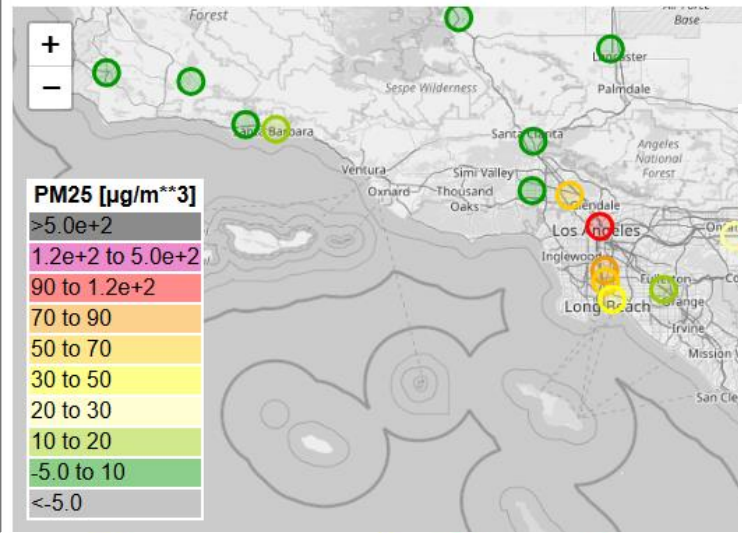
**Legend**

AirFuse PM2.5 ( $\mu\text{g}/\text{m}^3$ )

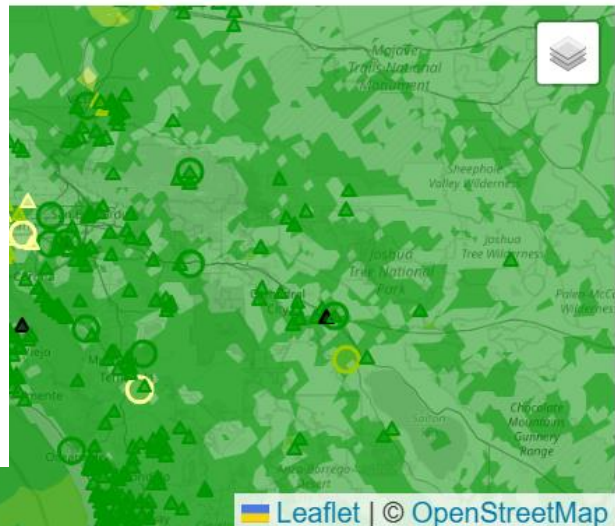
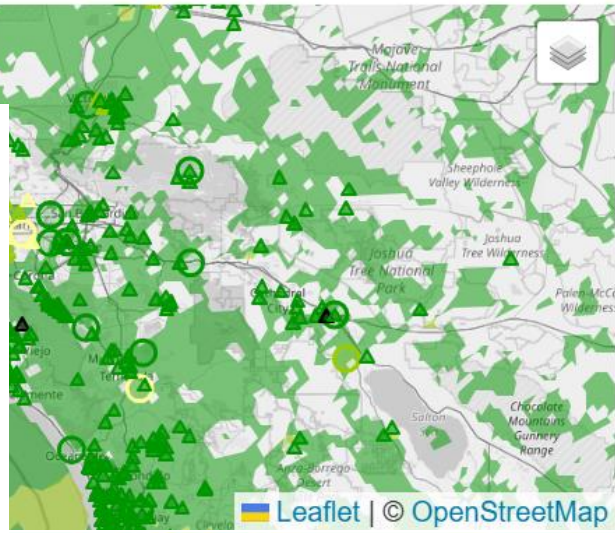
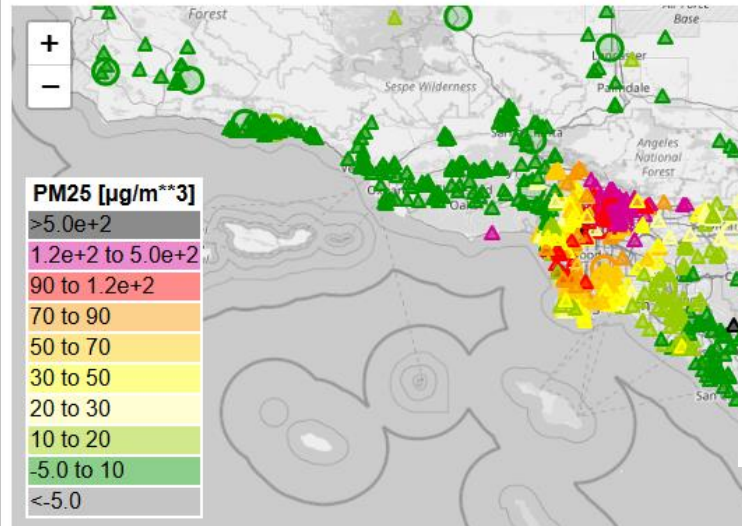
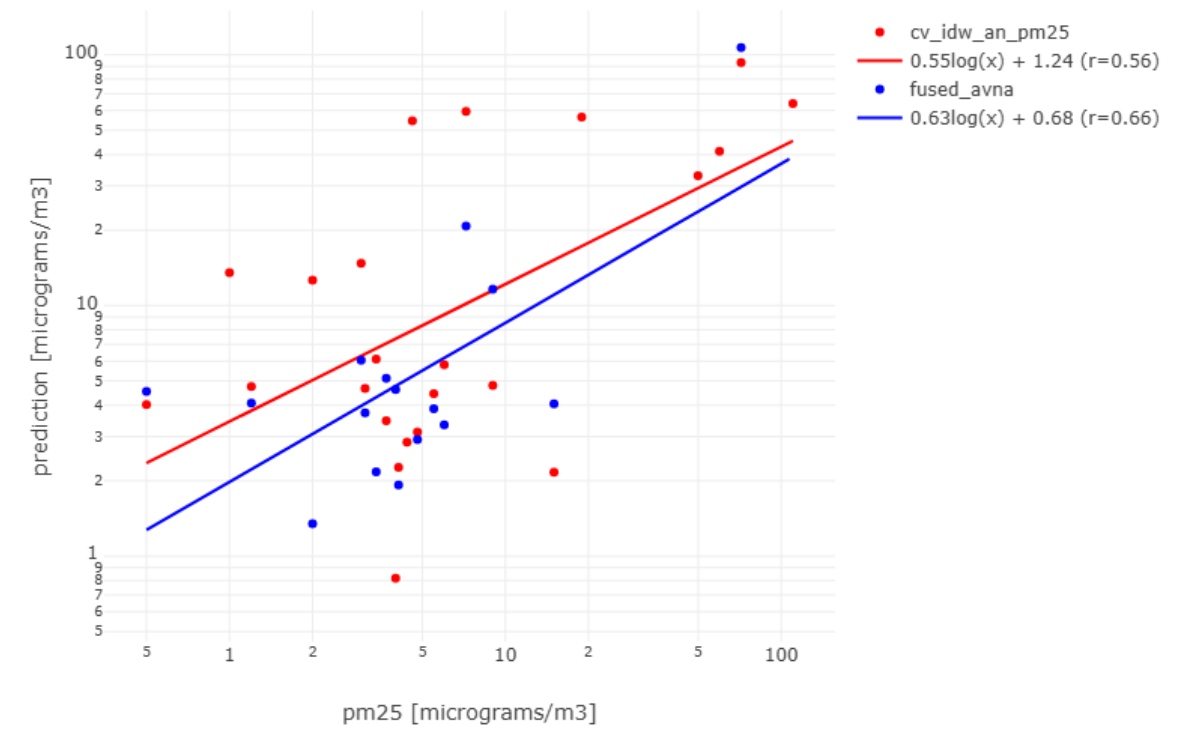
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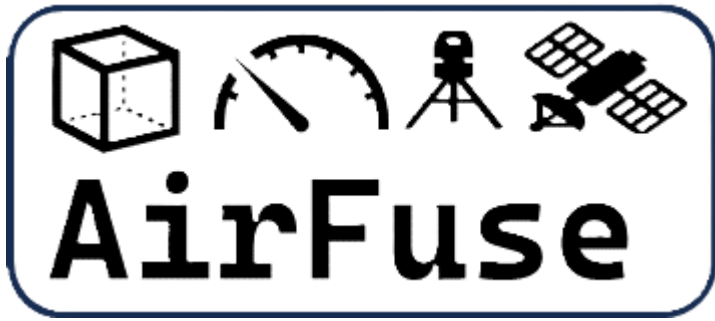


# Explained - Jan 9 12EST



Recall that both methods exactly equal the monitor without withholding.





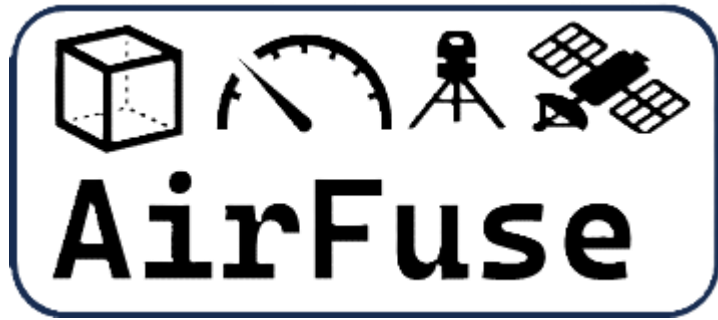
# Strengths and Weaknesses

## Pros

- In-house
- ***Simple method building on familiar eVNA***
- Direct weighting allows control
- Forecast model creates physical meaningful texture
- ***Creates 12 alternative estimates simultaneously***

## Cons

- In-house
- ***Voronoi neighbors are slow***
- Forecast model texture is not always “right”
- Weighting does not provide formal uncertainty analysis



## Summary

- Integrates forecast models, low-costs sensors, and monitors
- Running in real-time since March 24, 2004
- Results generally outperform interpolation
  - At monitors, full application is always exactly right.
  - The value of evaluation is estimating performance away from monitors
- We are working with states to investigate results
  - Surprises occur when monitors were not reporting – rerun would help
  - Dust events highlight the need to control PurpleAir weighting.



Questions?

