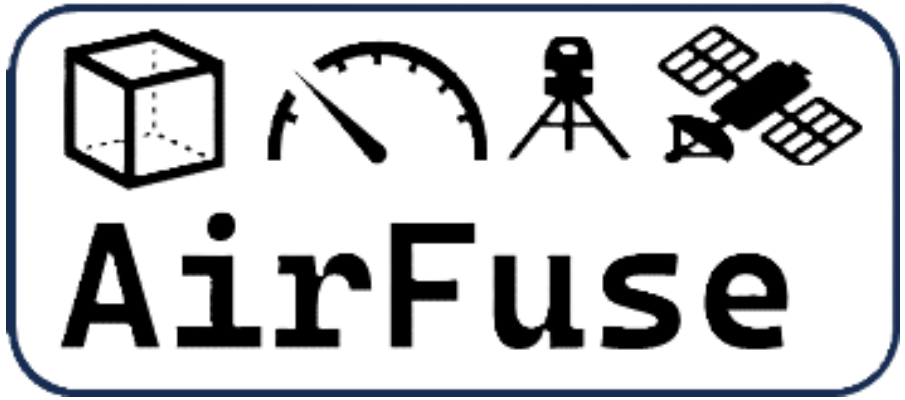
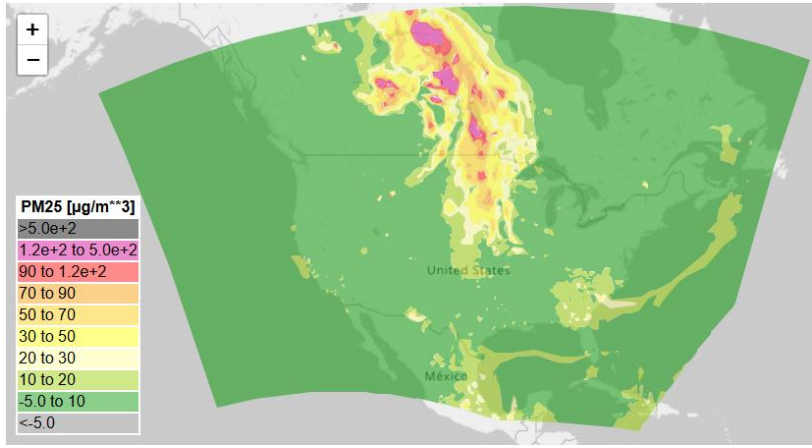




A multi-pollutant fusion system

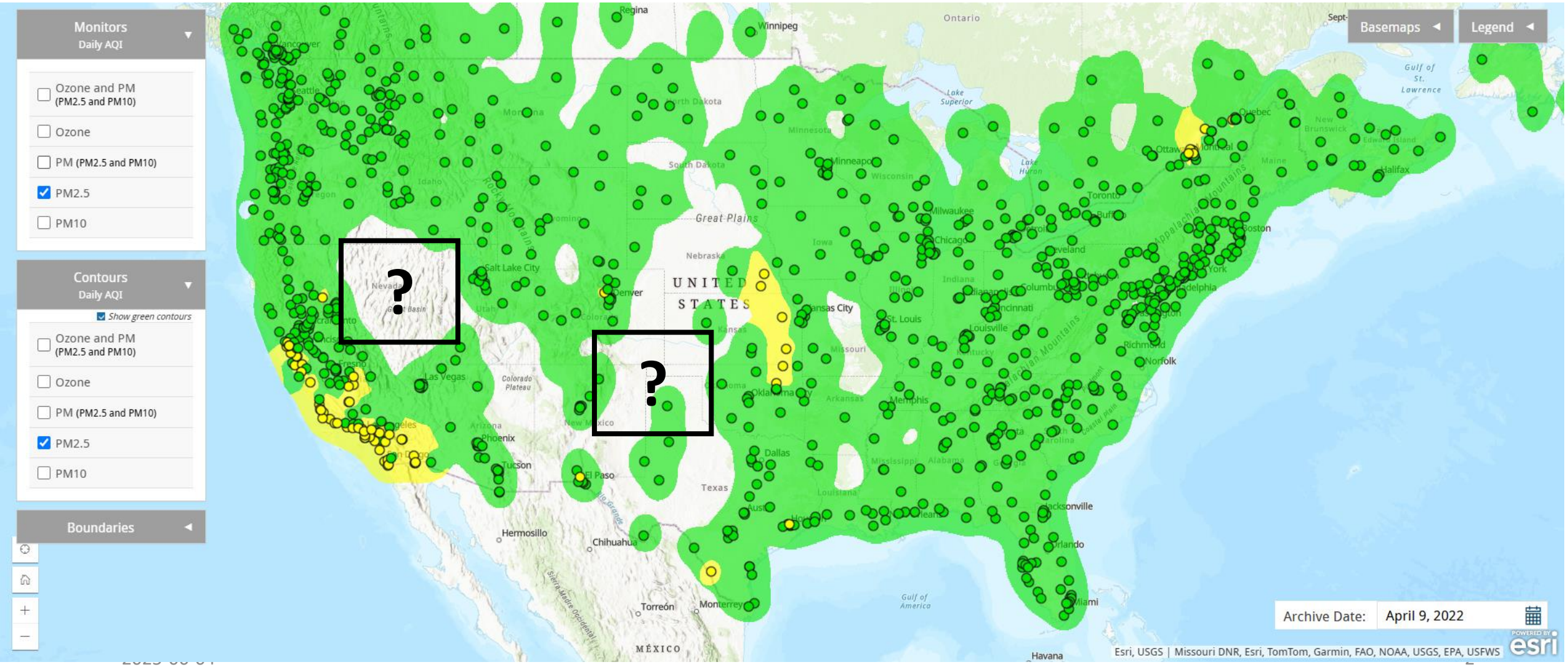
Barron H. Henderson[1,4]

Contributors: Phil Dickerson[1,4] Pawan Gupta[2,4], Shobha Kondragunta[3,4], Yang Liu[4,6], Meng Qi[6], Alqamah Sayeed, Hai Zhang[3,4], Janica Gordon[5], Halil Cakir[1], Brett Gantt[1], Benjamin Wells[1], Marcus Hylton[7], Youngsun Jung[9], and the HAQAST AirNow Teams[4]

[1]US EPA Office of Air Quality Planning and Standards; [2]National Aeronautics and Space Administration; [3]National Oceanic and Atmospheric Administration / National Environmental Satellite, Data, and Information Service; [4]NASA Health and Air Quality Applied Sciences Team and Tiger Teams; [5]North Carolina Agricultural and Technical State University; [6]Emory University; [7]AirNow Data Management Center; [9]National Oceanic and Atmospheric Administration / National Weather Service

***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.*

Jeff Pierce's HAQAST Showcase Example



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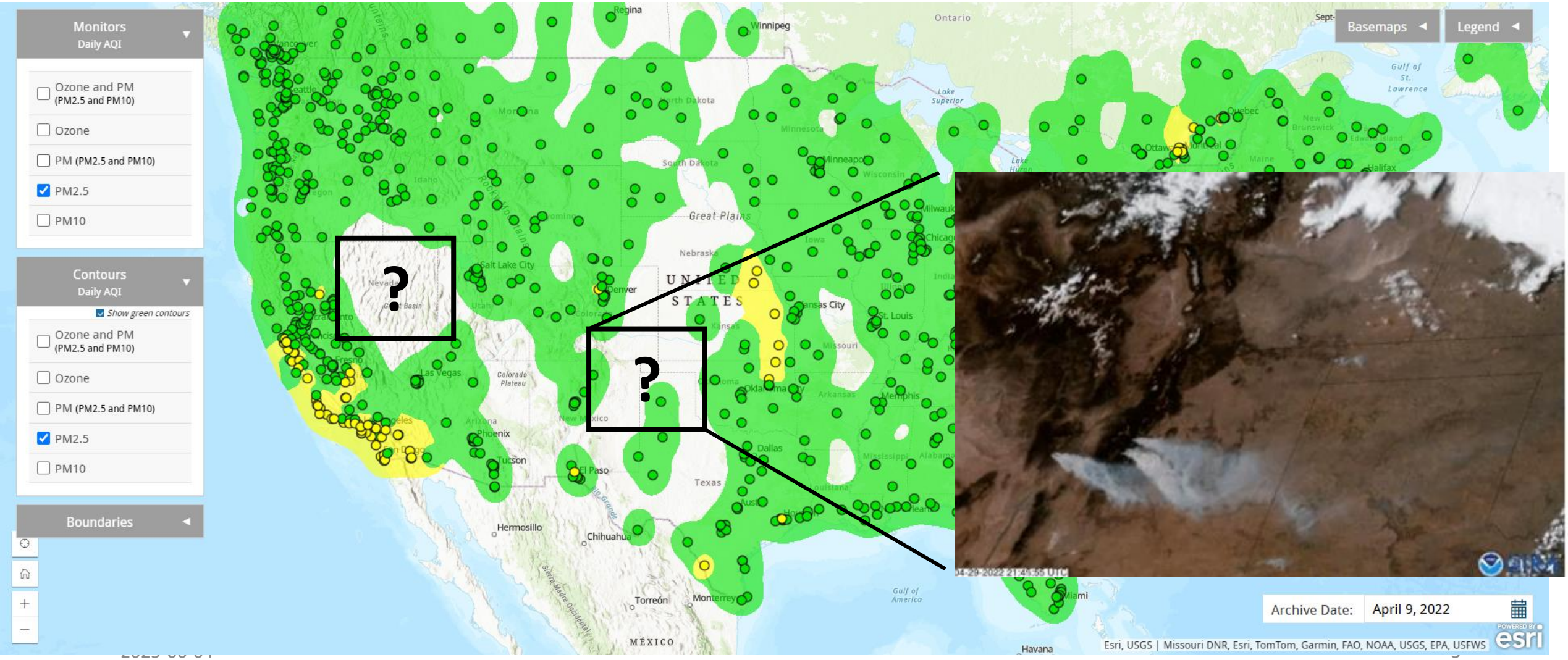
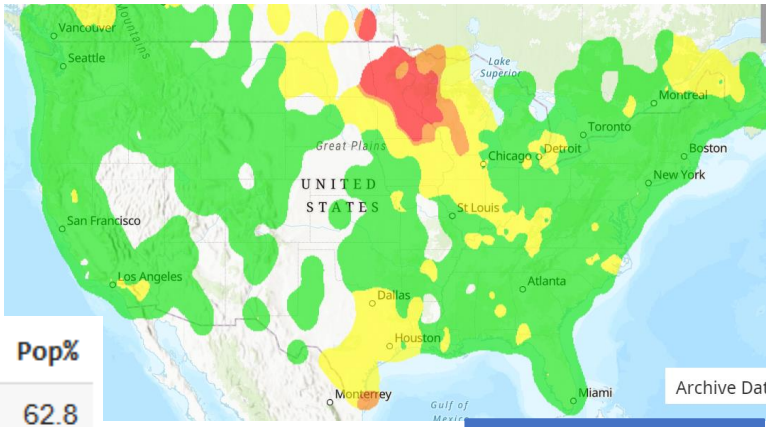
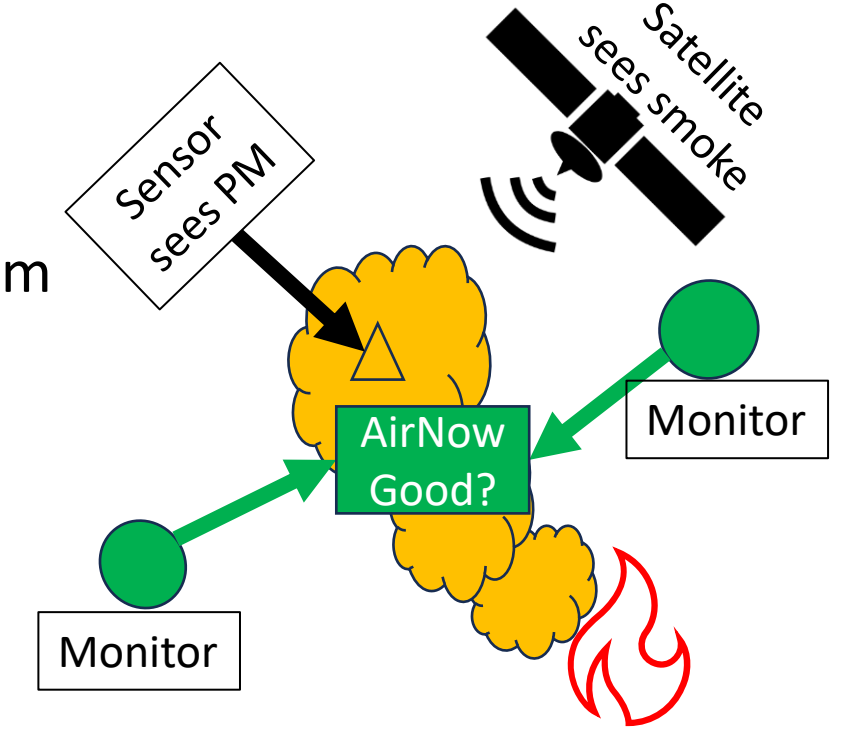


AirNow Vision: ultra-high-resolution data for all Americans!



*	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

- 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

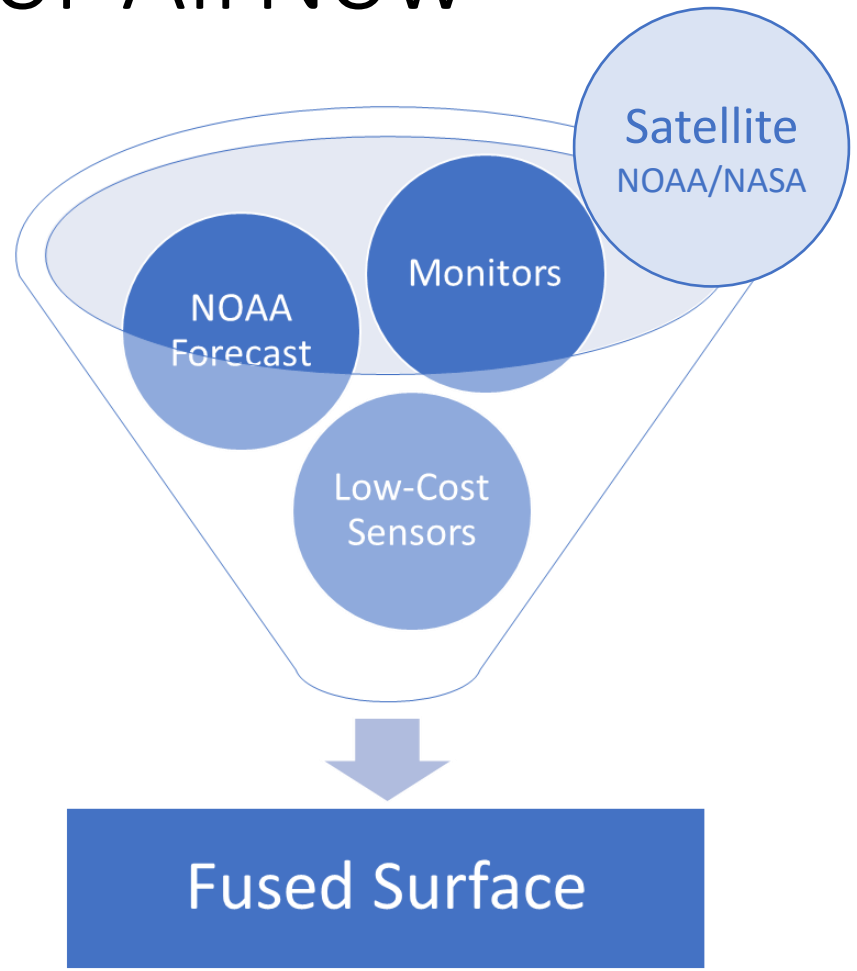


*County/Population from July 2024

Realtime hourly maps of $PM_{2.5}$ and ozone for AirNow

Best available data sources

- NOAA Forecast w/bias correction
- 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
- Ozone too, but no sensor or satellite data yet… Excited for TEMPO near-surface ozone



Available on airnowtech.org since March 2024

AirFuse timeline

Data Fusion Goals:
- NOAA Satellite to AirNow
- Added low-cost sensors
- Project published EM Sept

Pilot on AirNowTech.org:
- 1-hr Ozone; 1-hr PM25
- Every hour publicly available
- Get a free password to monitor!

2021 → 2022 → 2023 → Mar 2024 → Today

NASA/NOAA/EPA HAQST Collab:
- EPA OAQPS/OID/ORD
- NOAA NESDIS
- NASA HAQAST: "Incorporating Satellite Data Updates into AirNow"

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

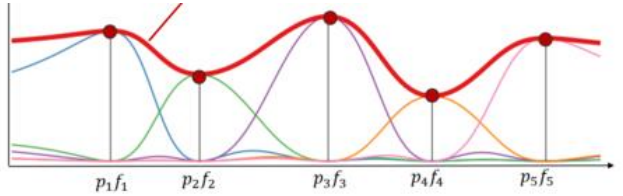
Ongoing Application:
- 1-year+ live on AirNowTech
- Collecting feedback from states
- Preparing for more public release

Bratburd et al. EM Plus 2022; Henderson et al., 2022, 2023a,b,c,d,2024a,b,c

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

$$f_x = f_i w_i$$

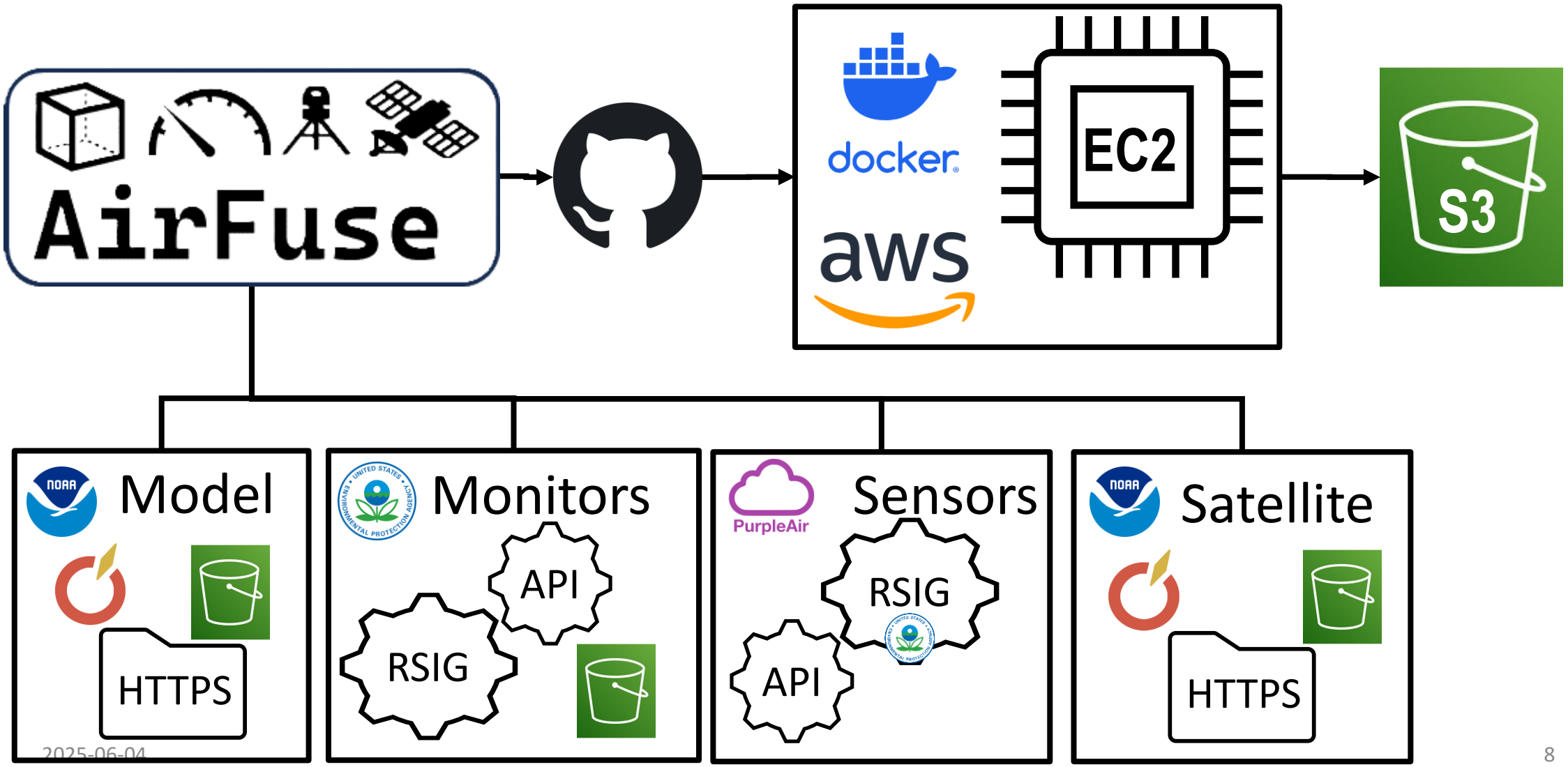


Wikipedia: Inverse Distance Weighting as a sum of all weighting functions for each sample point.

$$w_i = \frac{\|p_i - x\|^{-2}}{\sum_i \|p_i - x\|^{-2}}$$

*interpolating bias is like eVNA, but additive

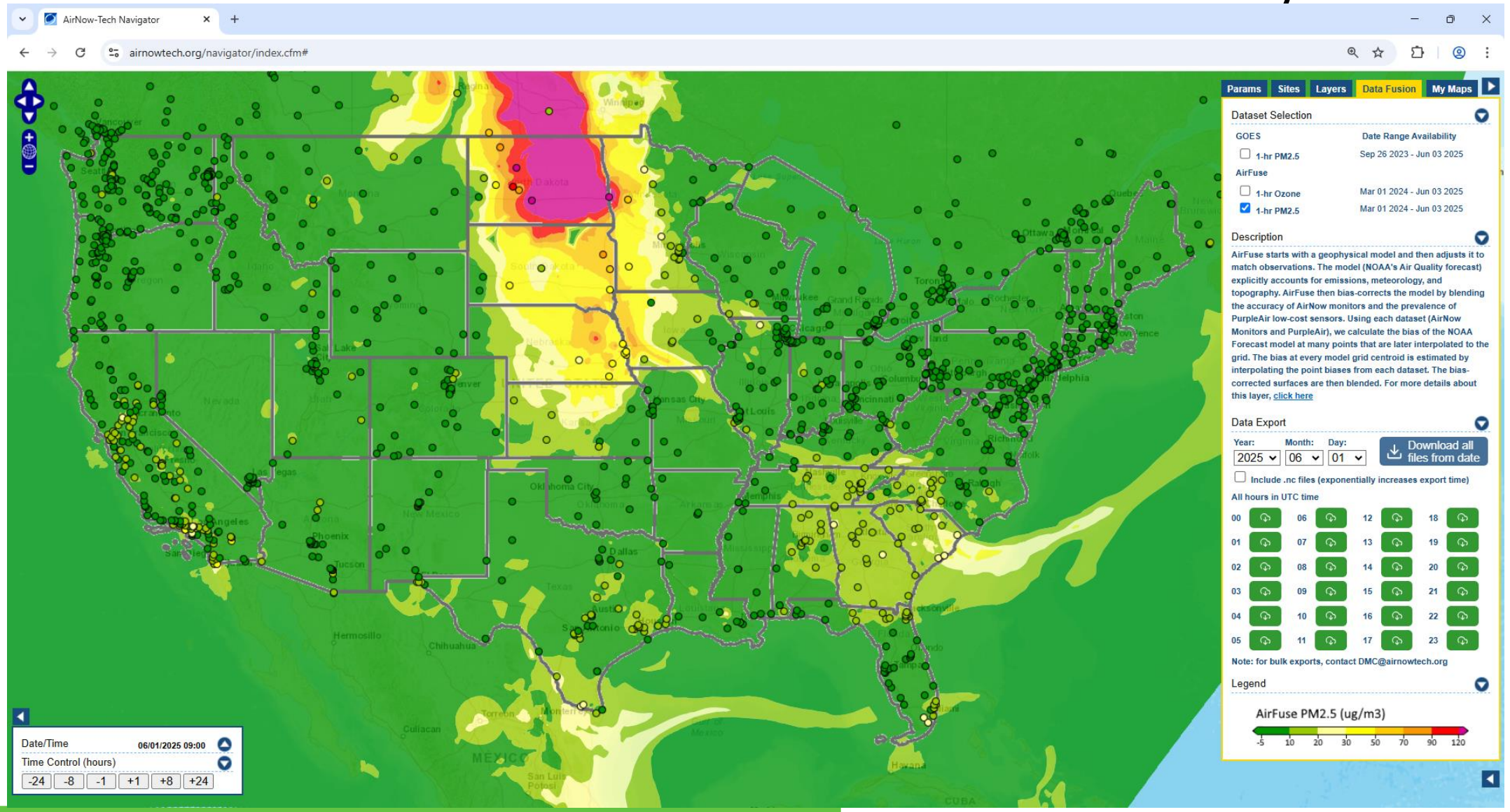
AirFuse runs in the cloud (or locally)



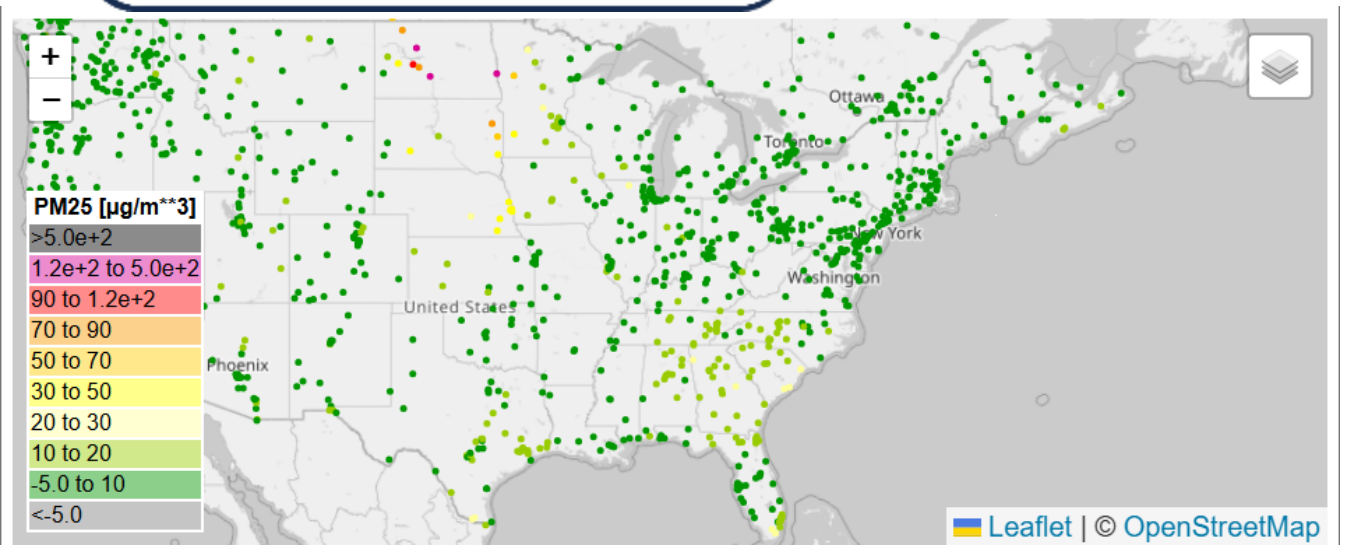
What are the biggest needs?

- Quality Assurance Challenges
  - Large changes from one hour to the next can indicate instrument error or “events”
  - Monitors measuring events (dust or fire) should be included.
  - Instrument error should be with held.
  - Typical automated QA may not distinguish.
- Dynamic quality assurance
  - GOES-PM25 or AirFuse surfaces are only as good as the inputs.
  - If monitors are not reporting, GOES-PM25 and AirFuse cannot calibrate.

AirNowTech - June 1 09EST Case Study



AirFuse Explained - June 1 09EST



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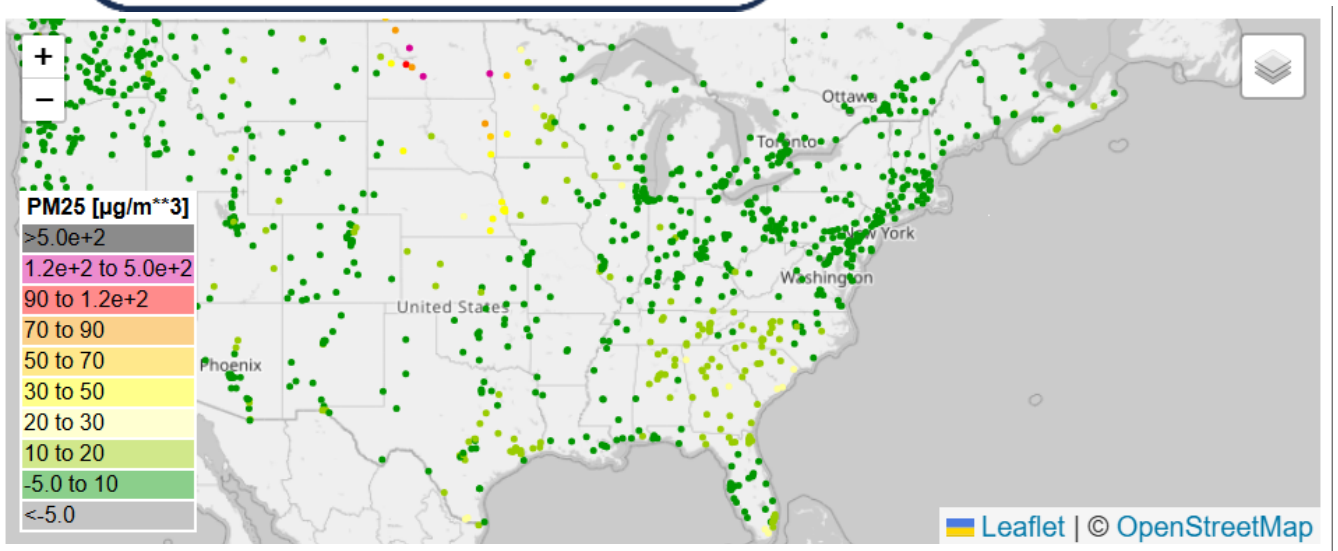

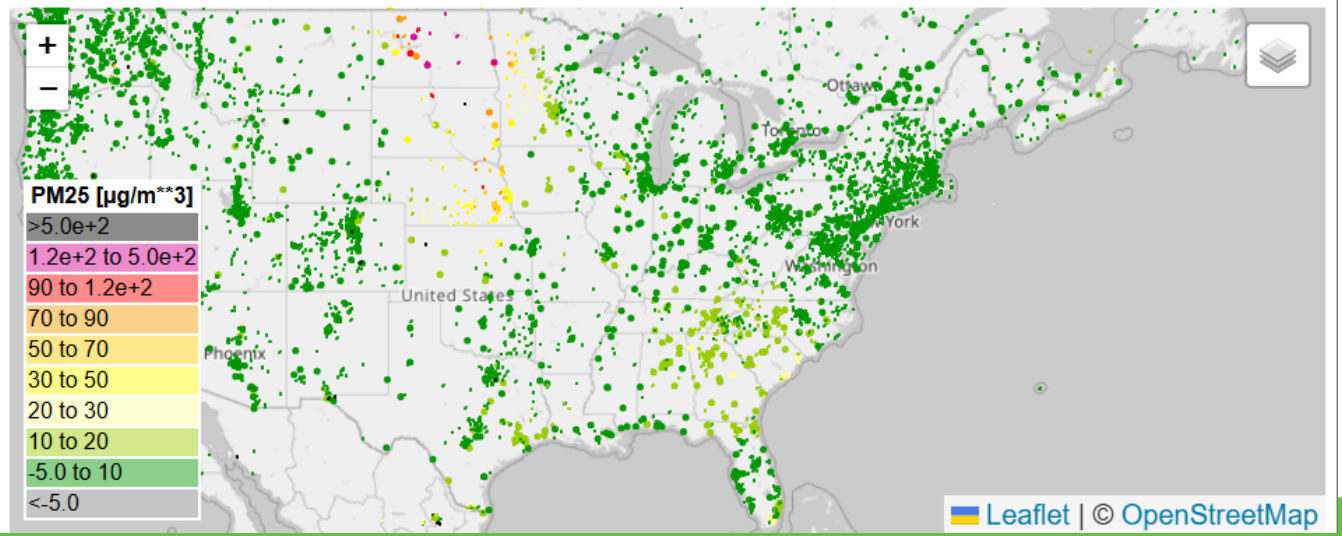

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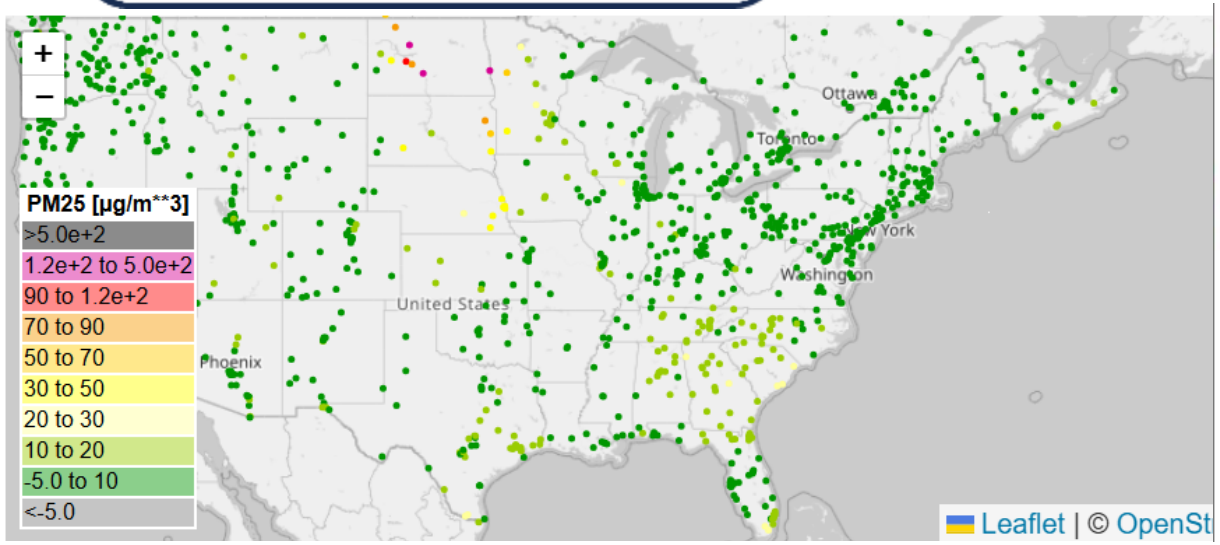
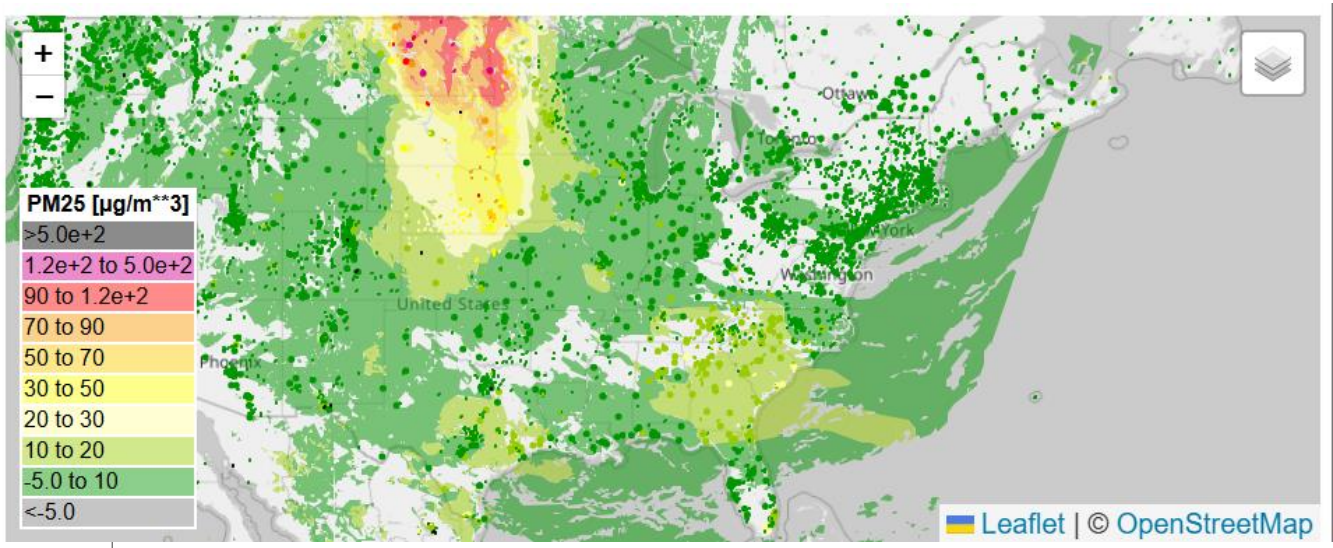
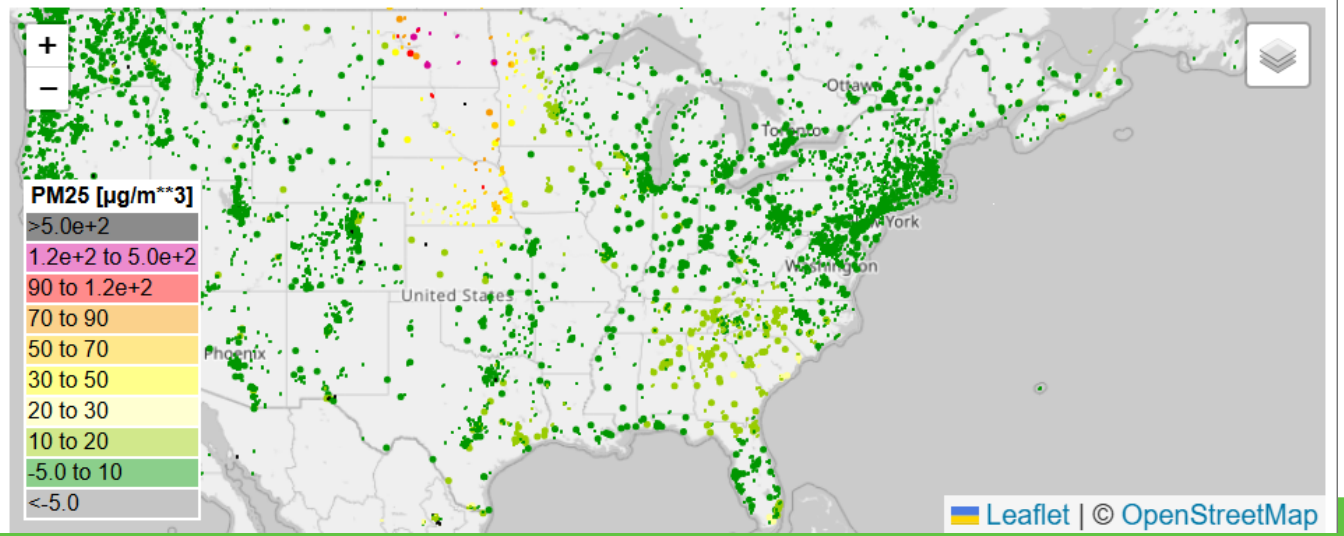
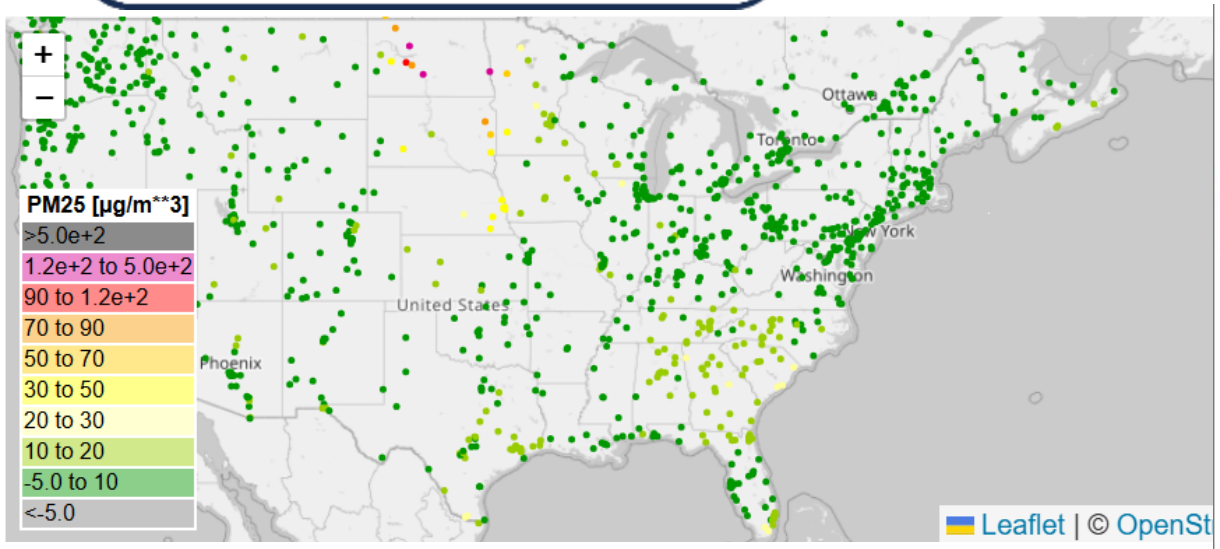


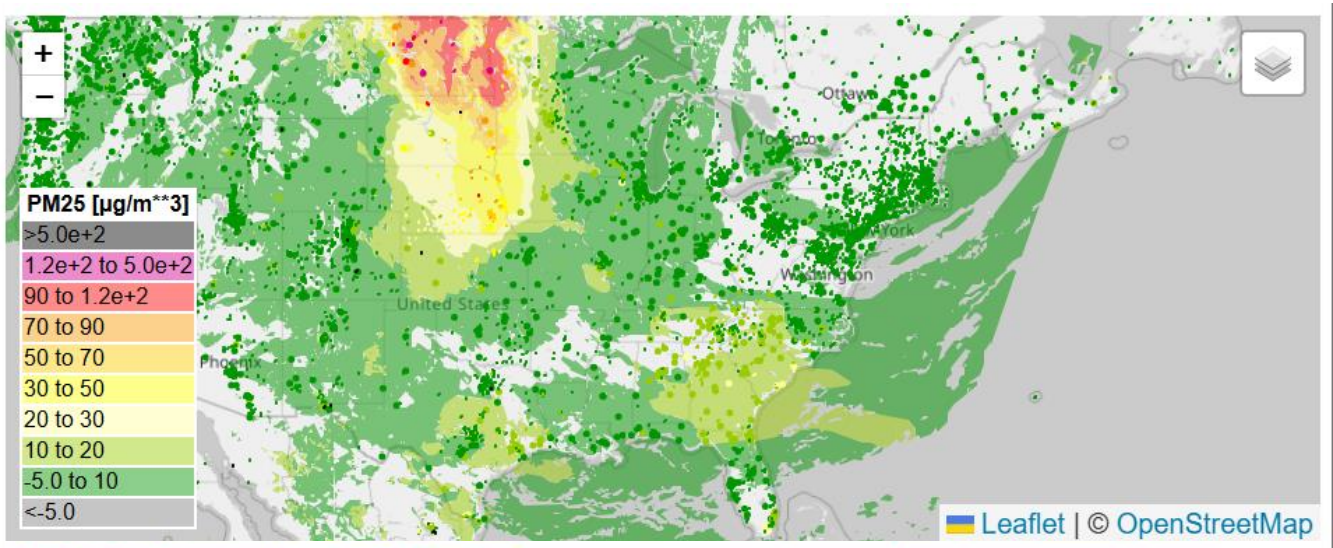


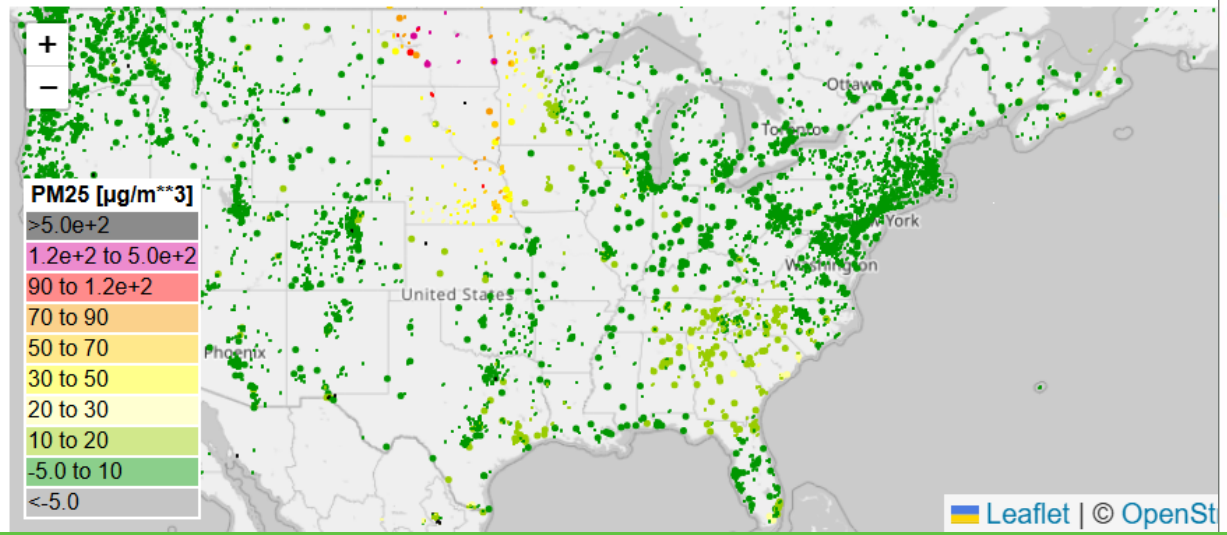


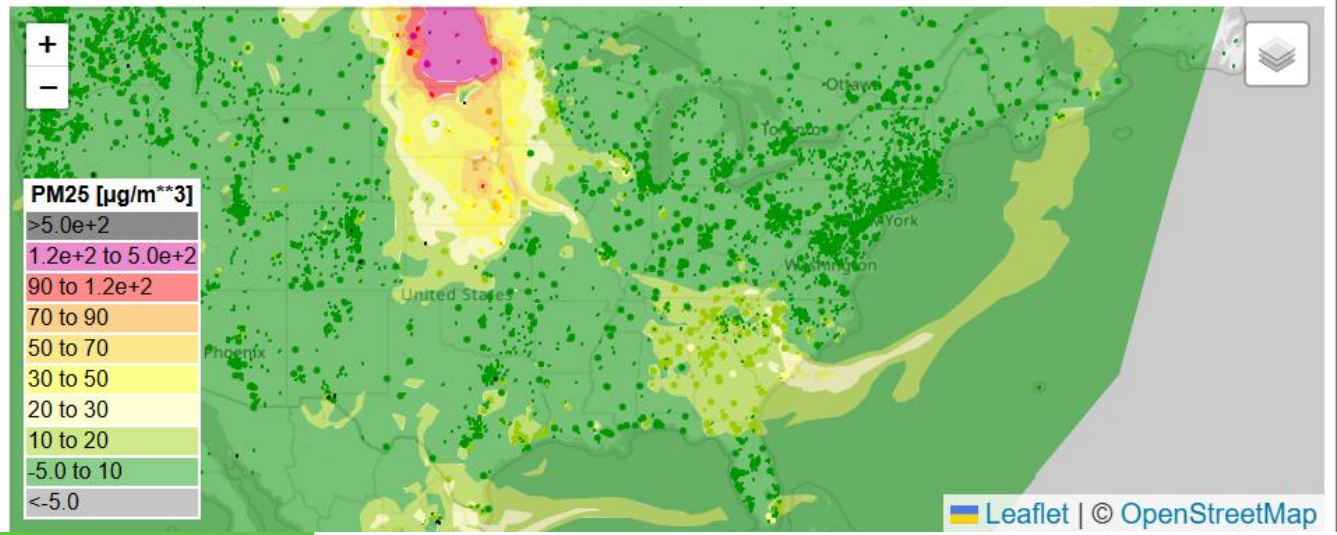
AirFuse

Explained - June 1 09EST









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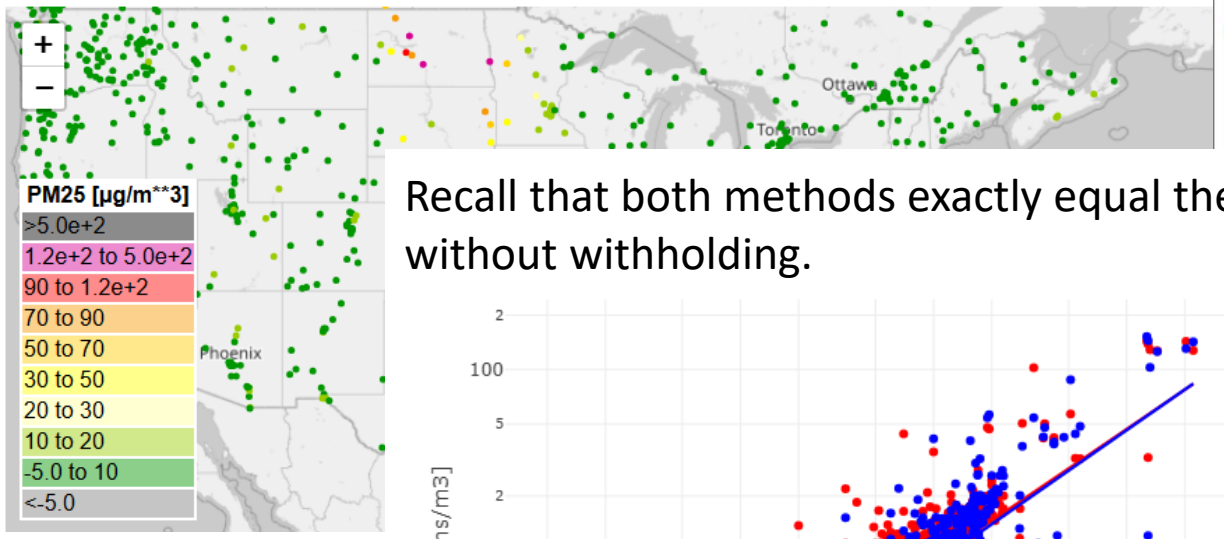
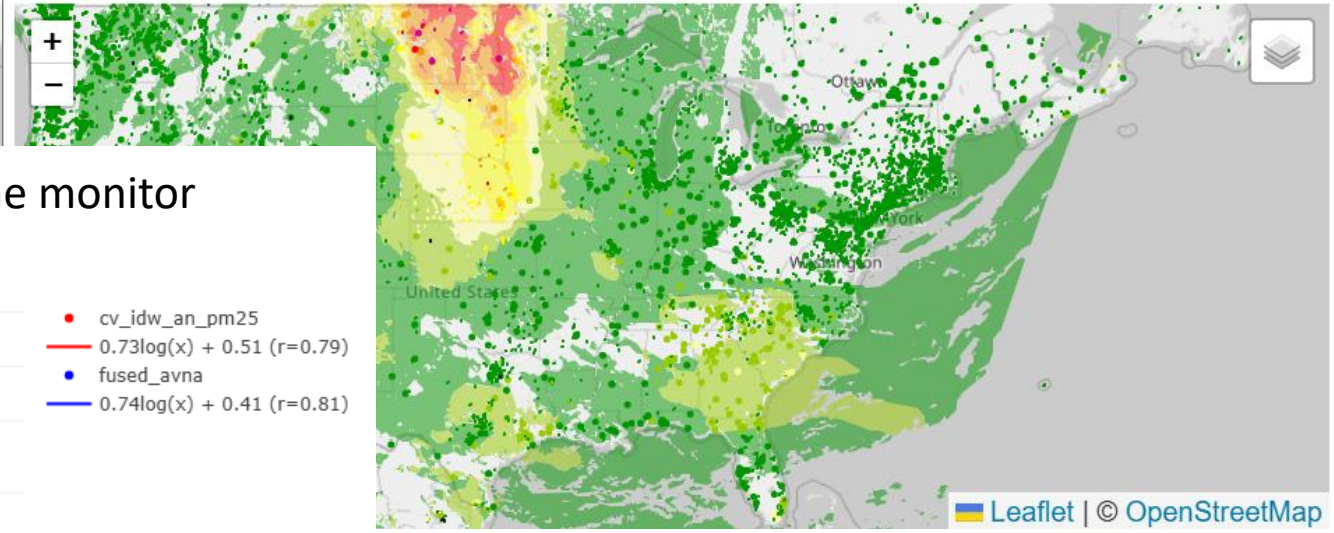
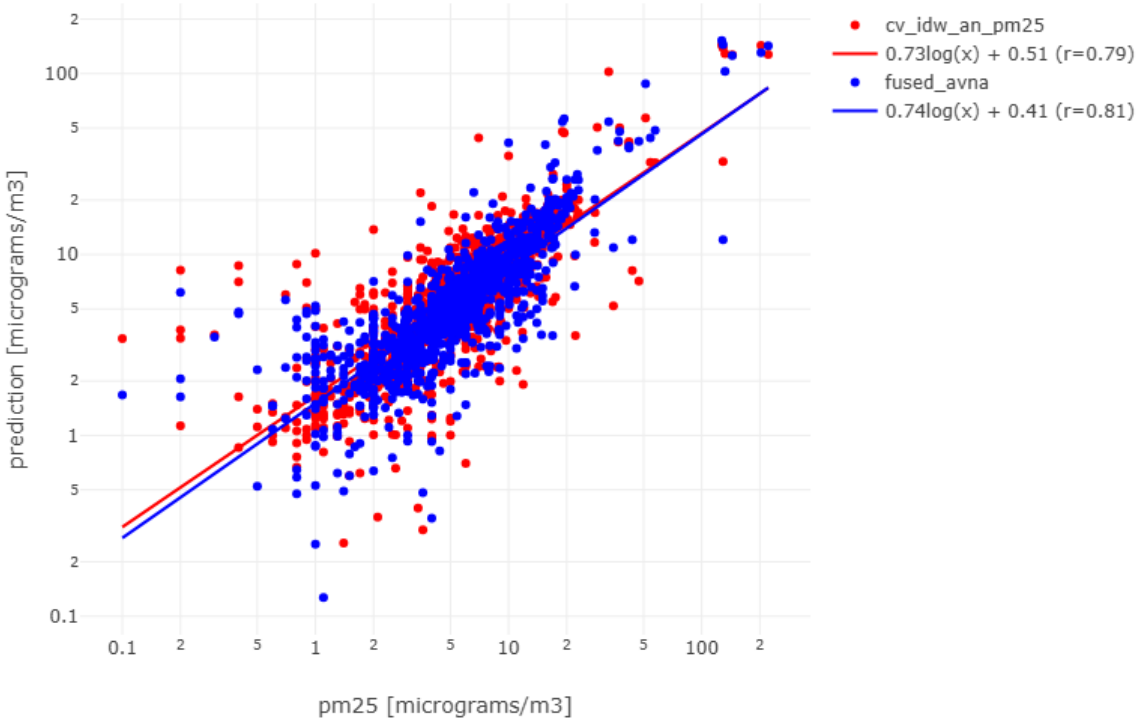
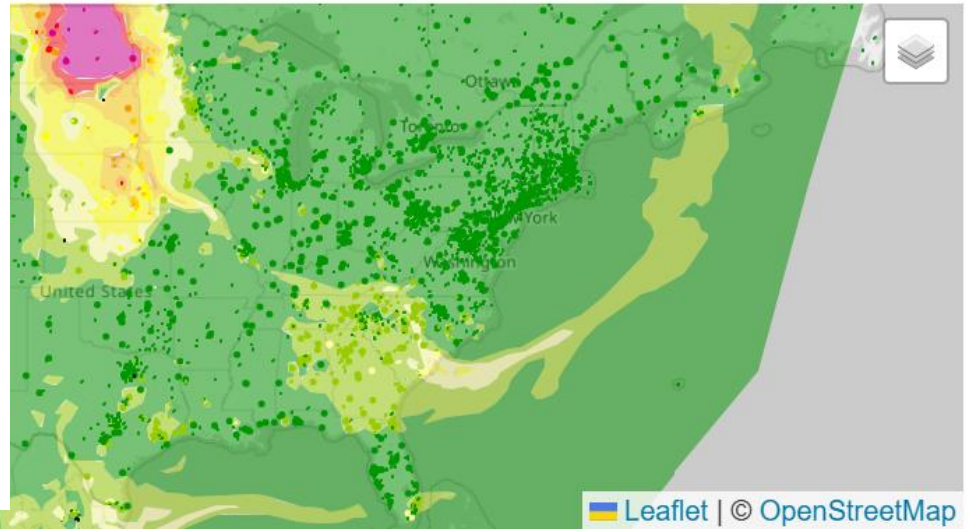


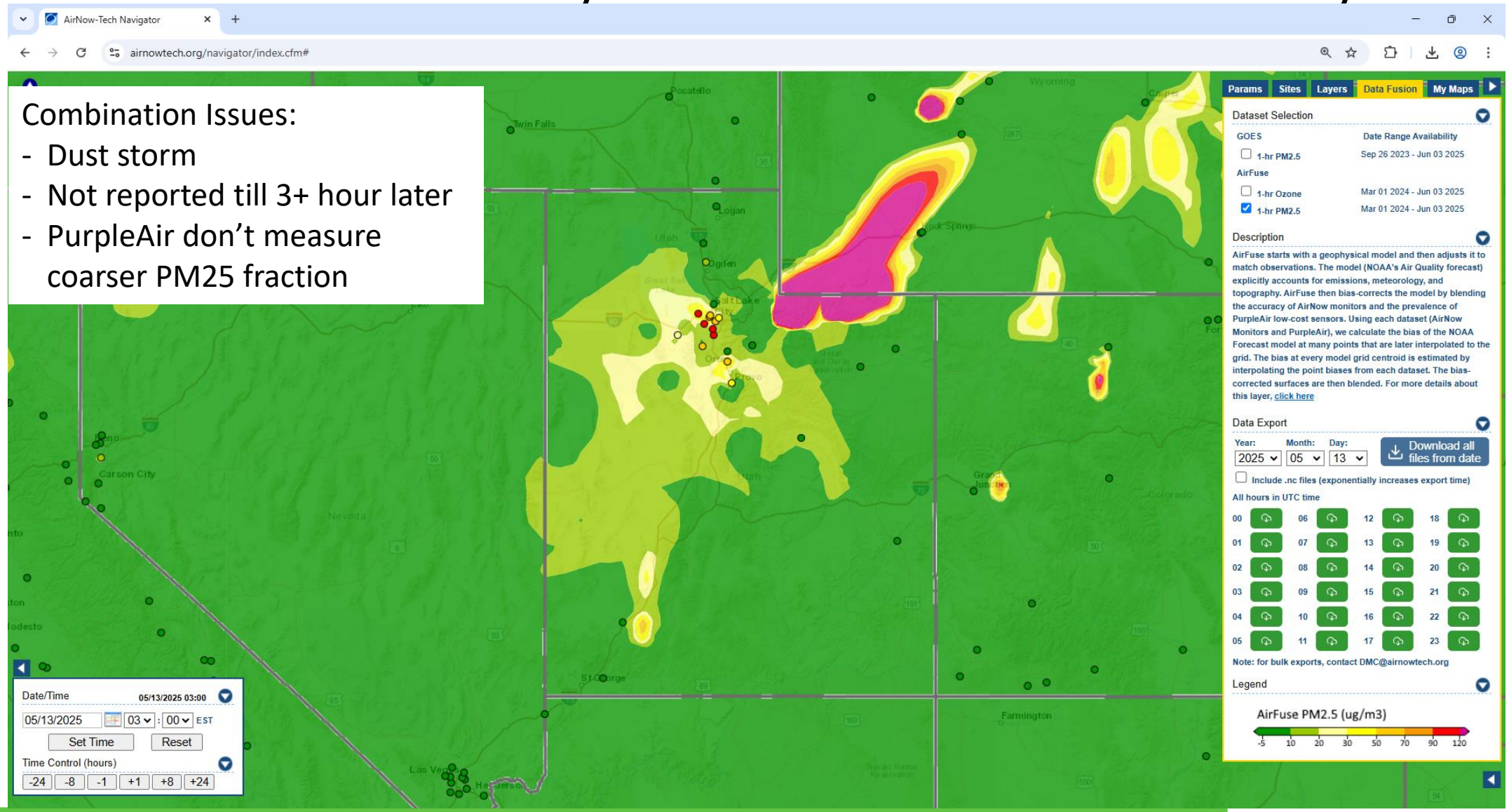


Recall that both methods exactly equal the monitor without withholding.



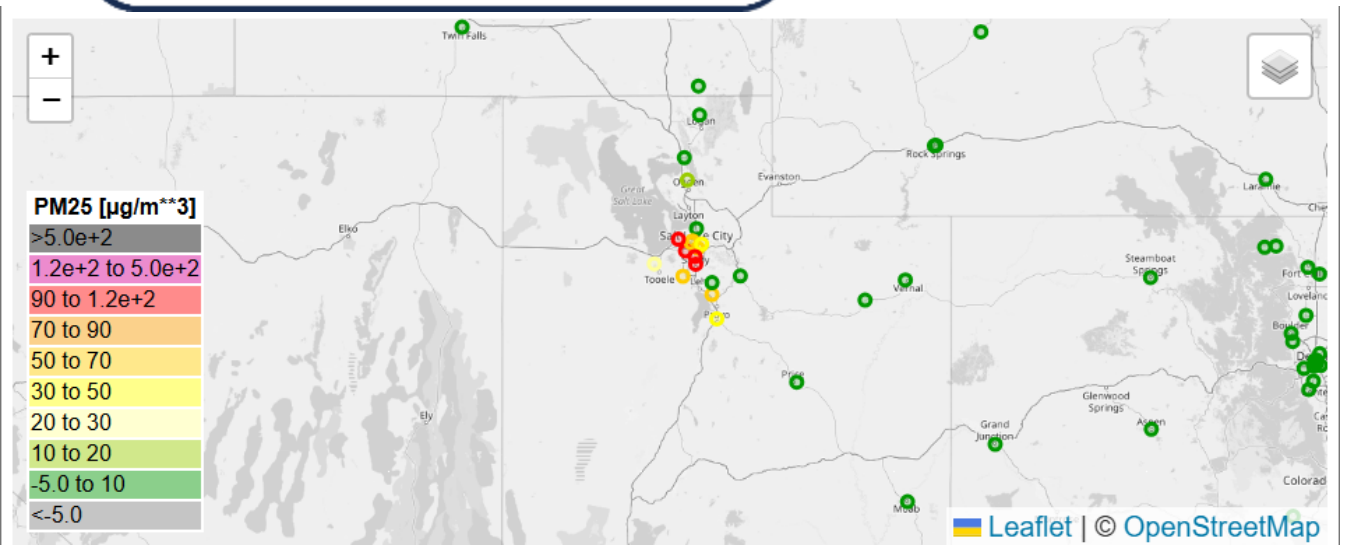


AirNowTech May 14 – 03EST Case Study



AirFuse

Explained - May 14 04EST



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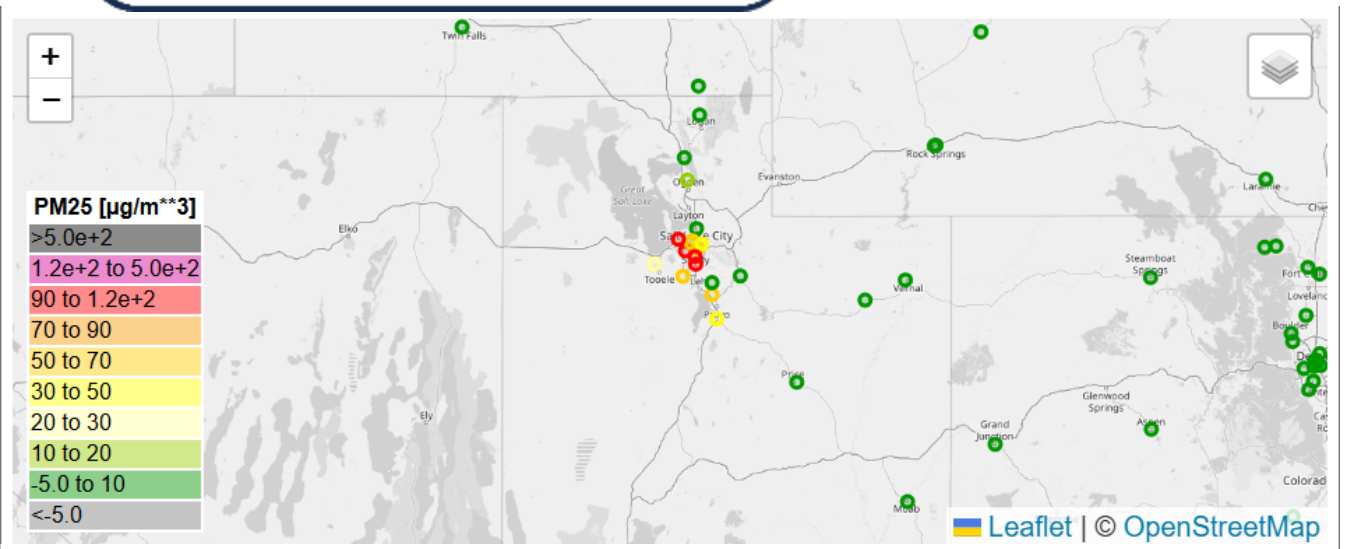
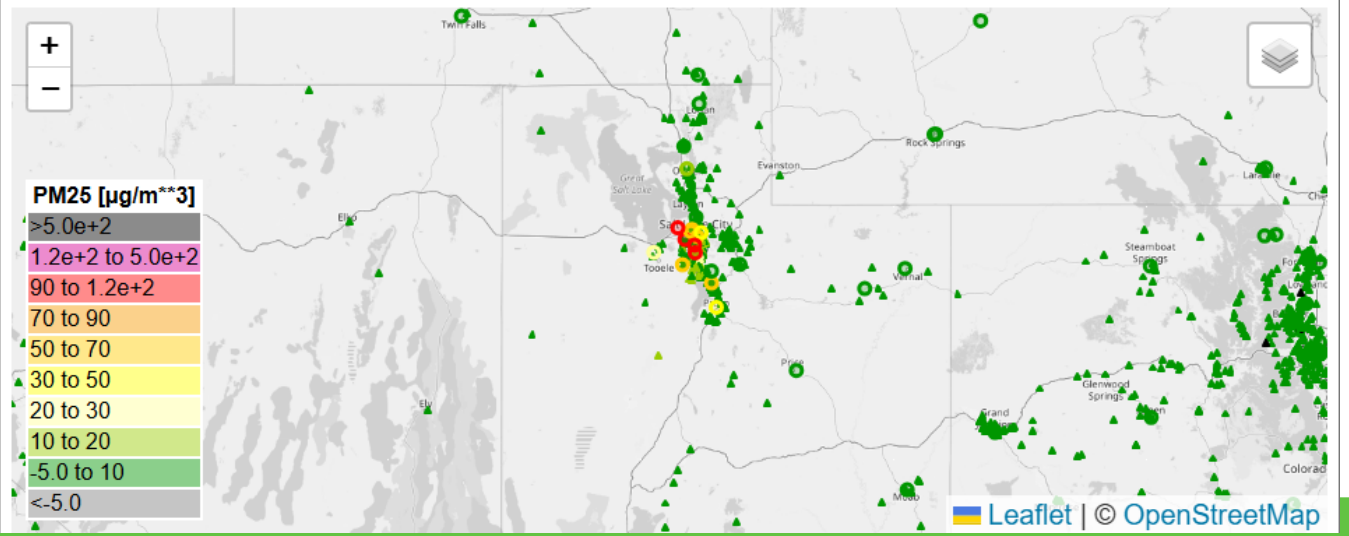
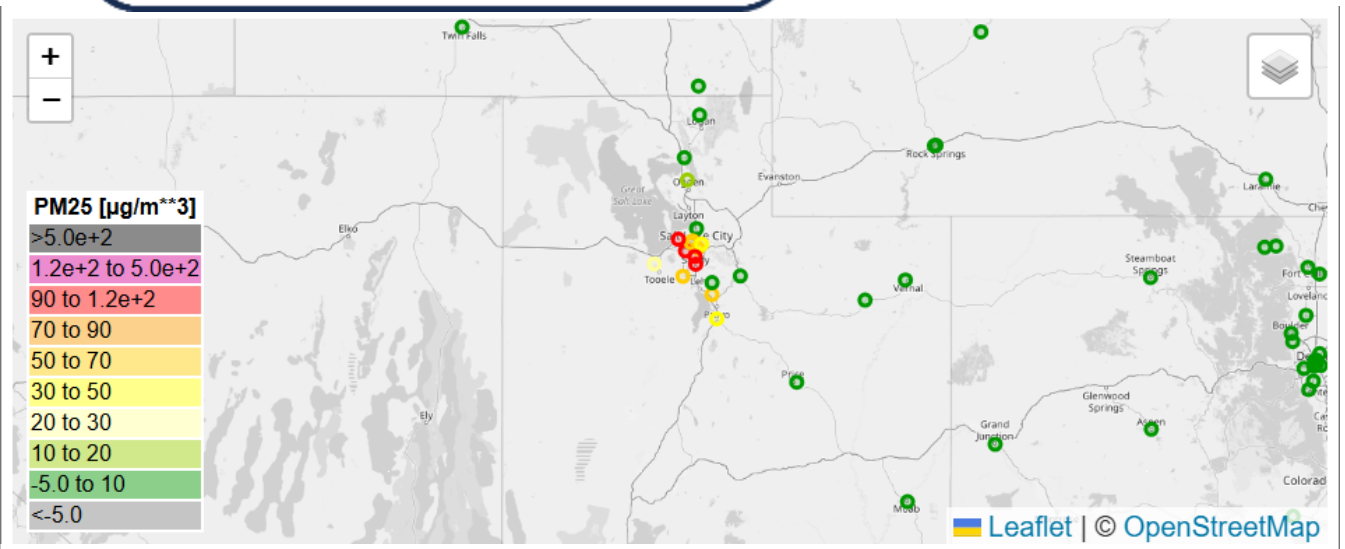
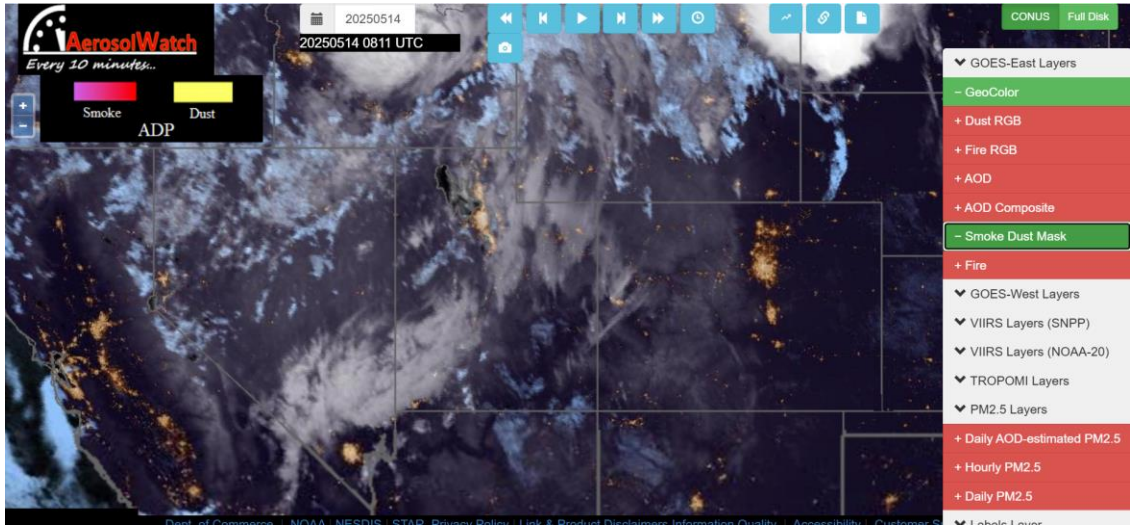
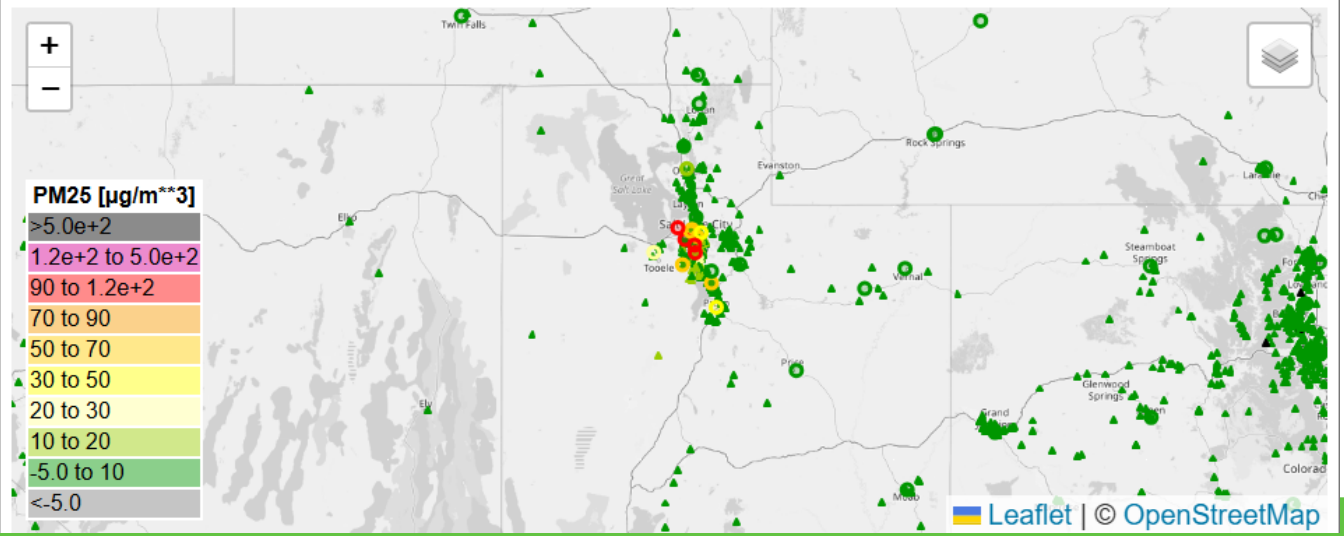




AirFuse Explained - May 14 04EST







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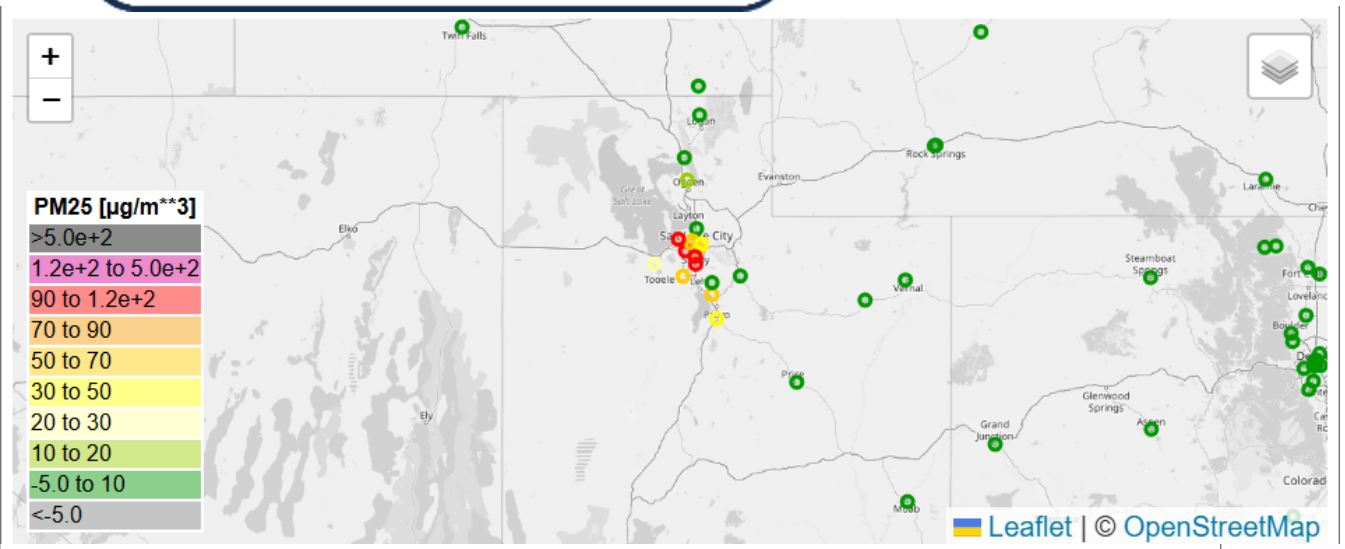

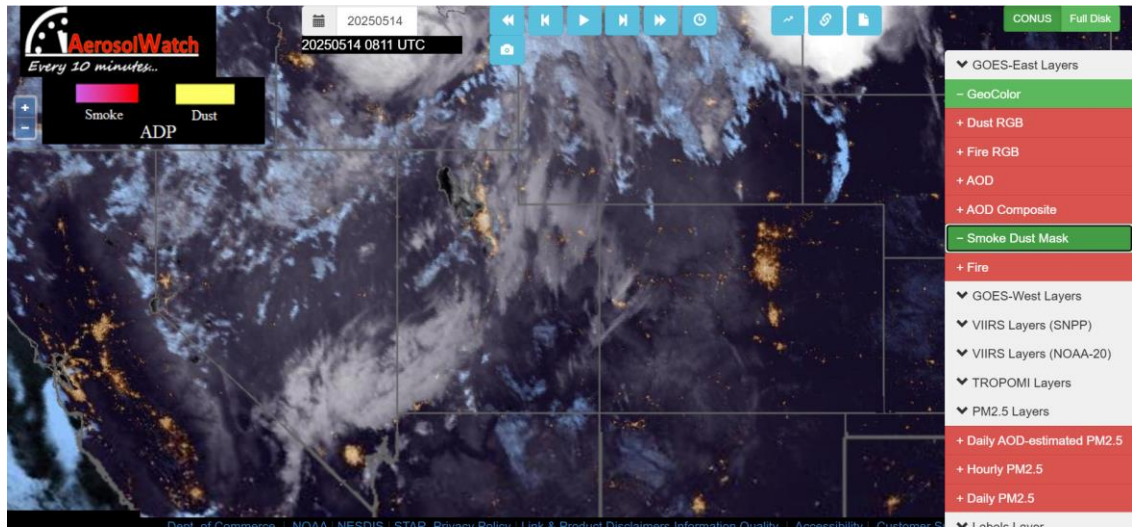

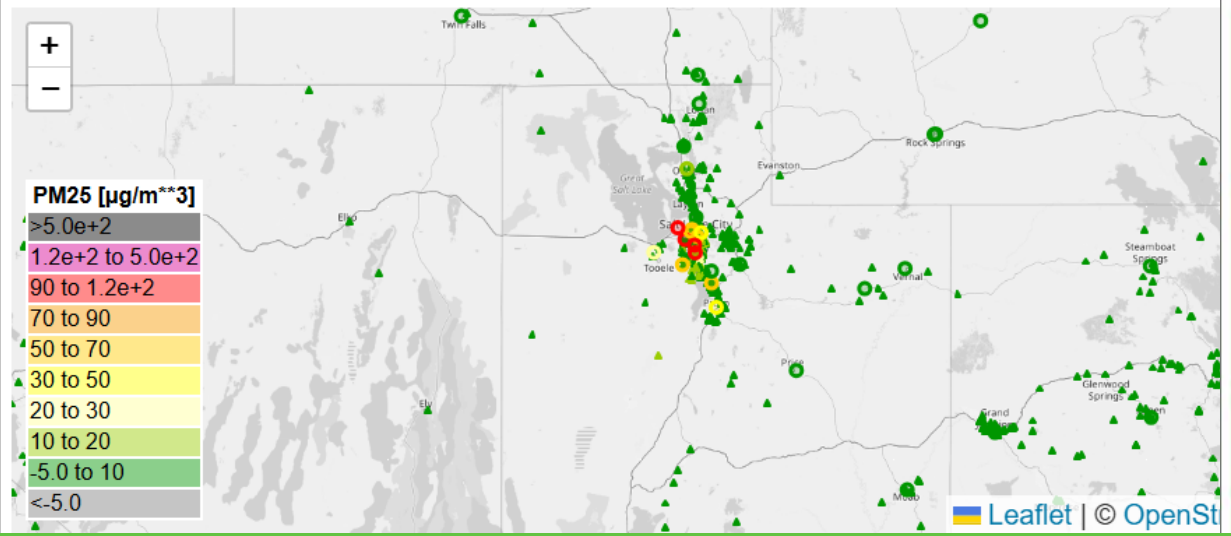

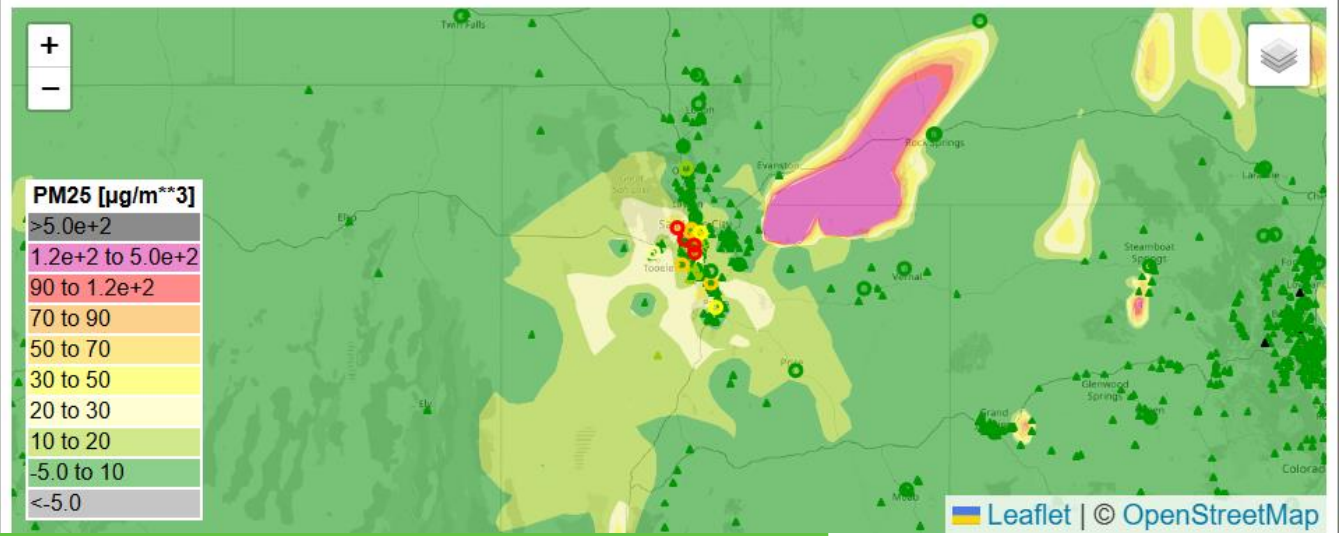

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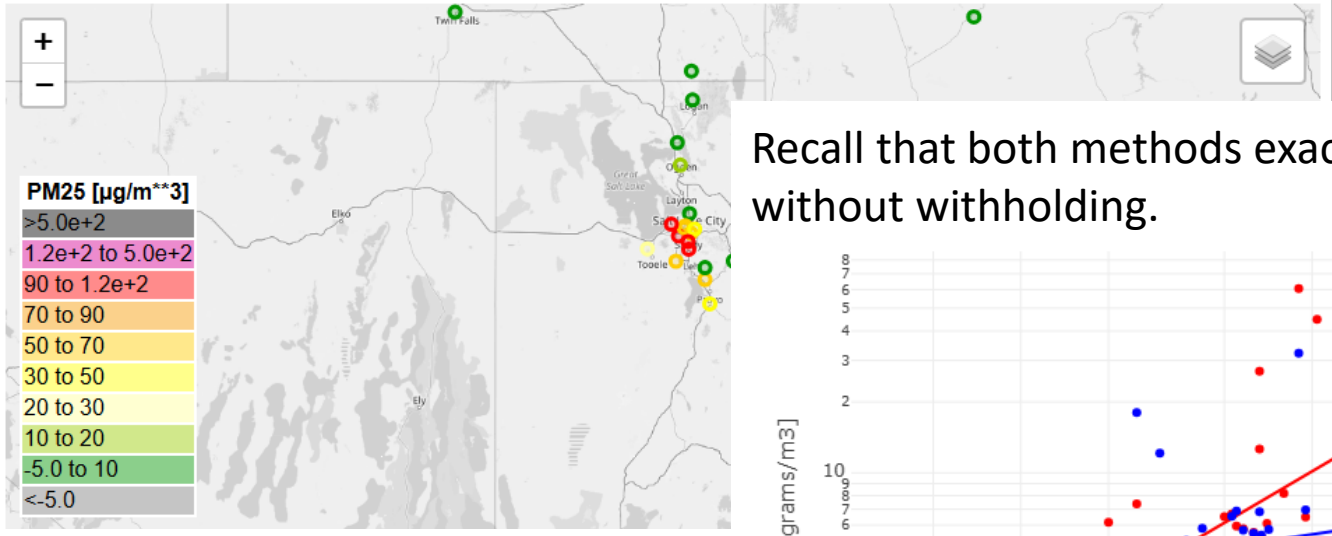

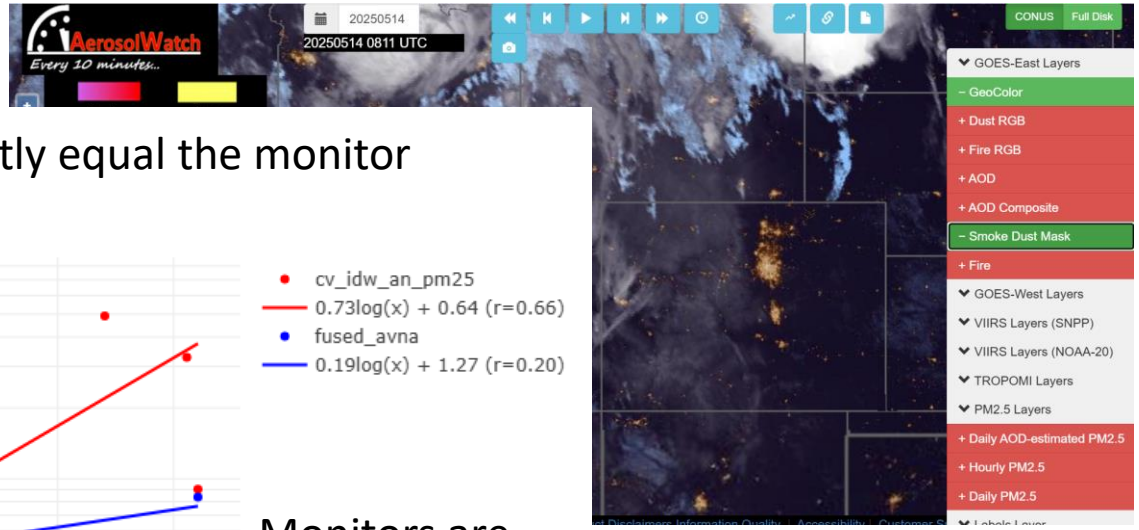

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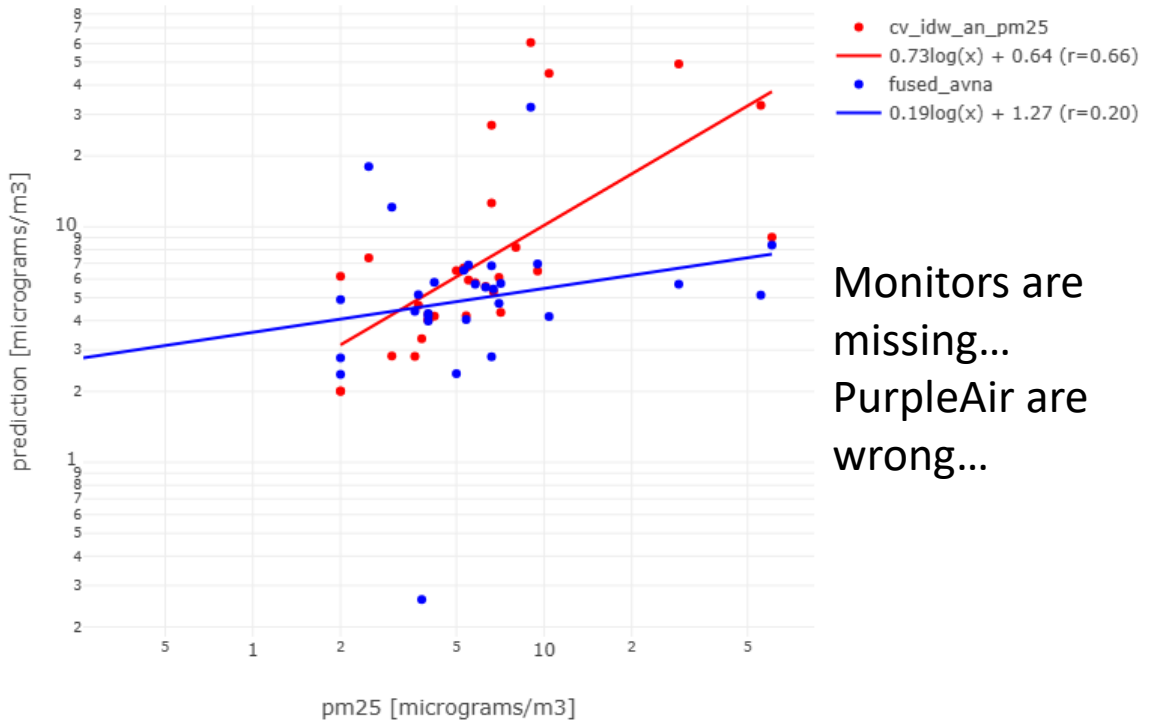
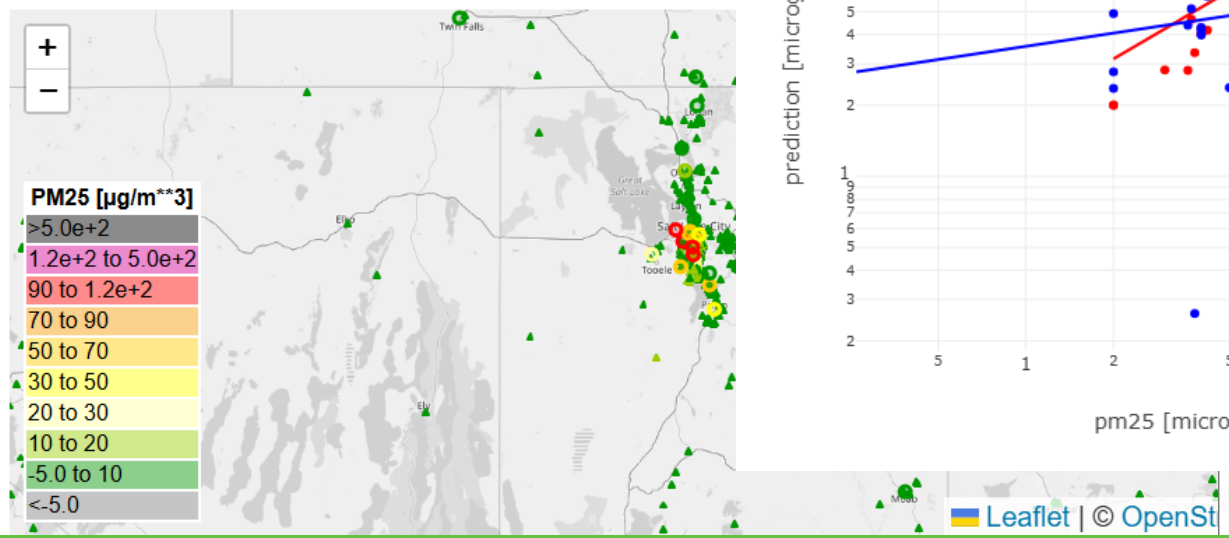
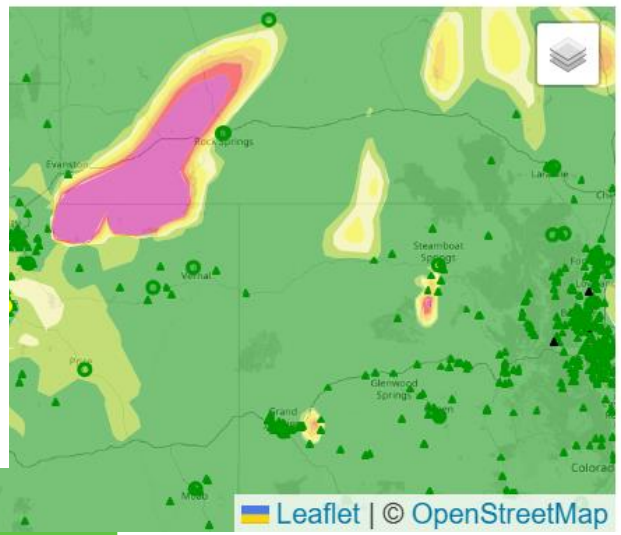


Monitors are missing…
PurpleAir are wrong…





Next Steps

- AirFuse integrates forecast models, low-costs sensors, and monitors
  - Running in real-time since March 24, 2004
  - Currently without GOES-PM25
  - (not shown) Computer “vision” can help identify discontinuities.
  - Excited about TEMPO improvements GOES-PM25
- Needs that satellites can help
  - Events (fires and dust) trigger monitor QA flagging – data is withheld from fusion.
    - Can states use satellite data to dynamically modify QA thresholds?
  - Dust events highlight the need to dynamically weight PurpleAir.
    - Can satellite wavelength-specific AOD provide guidance?
    - What other tools are available?
  - Night-time data products are a need that hasn’t been met.

Questions?

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