Multi-Agency Ensemble Wildfire $PM_{2.5}$ Forecast: Towards Community Consensus

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1 – GMU; 2 – NOAA ARL; 3 – NRL; 4 – NOAA NESDIS/STAR; 5 - NASA GSFC; 6 - UMBC/JCET; 7 - NOAA GSL; 8 – NOAA NWS/EMC

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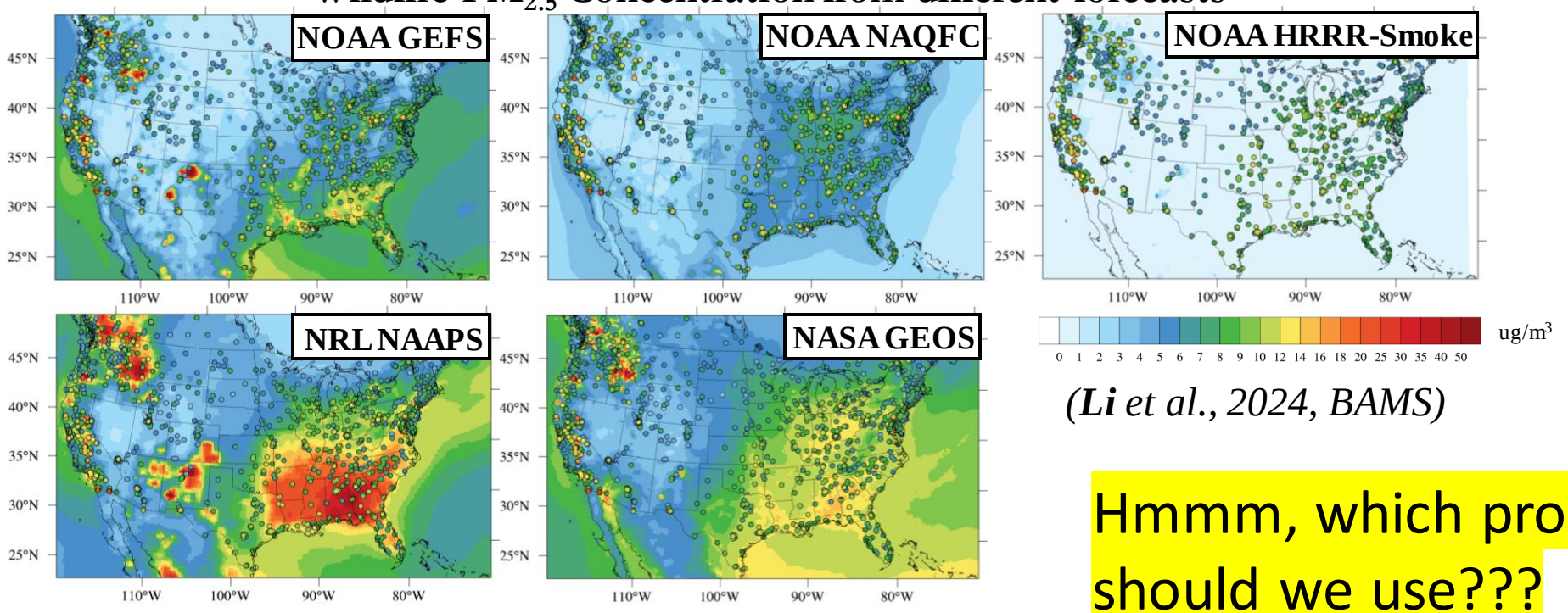
Wildfire Air Quality Forecasts

- Air quality forecasting is a key tool to inform air quality and health managers to mitigate the damages caused by wildfires.
- Great uncertainties in wildfire air quality forecast.

Wildfire $PM_{2.5}$ Concentration from different forecasts



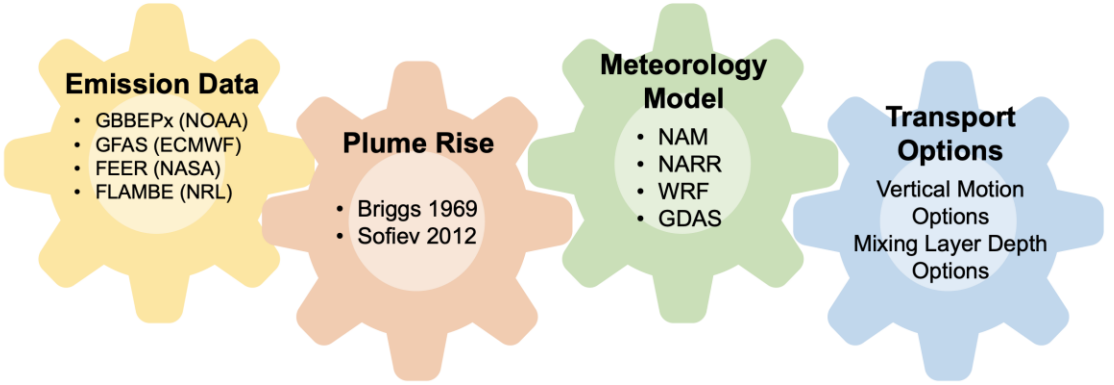
*(**Li** et al., 2024, BAMS)*

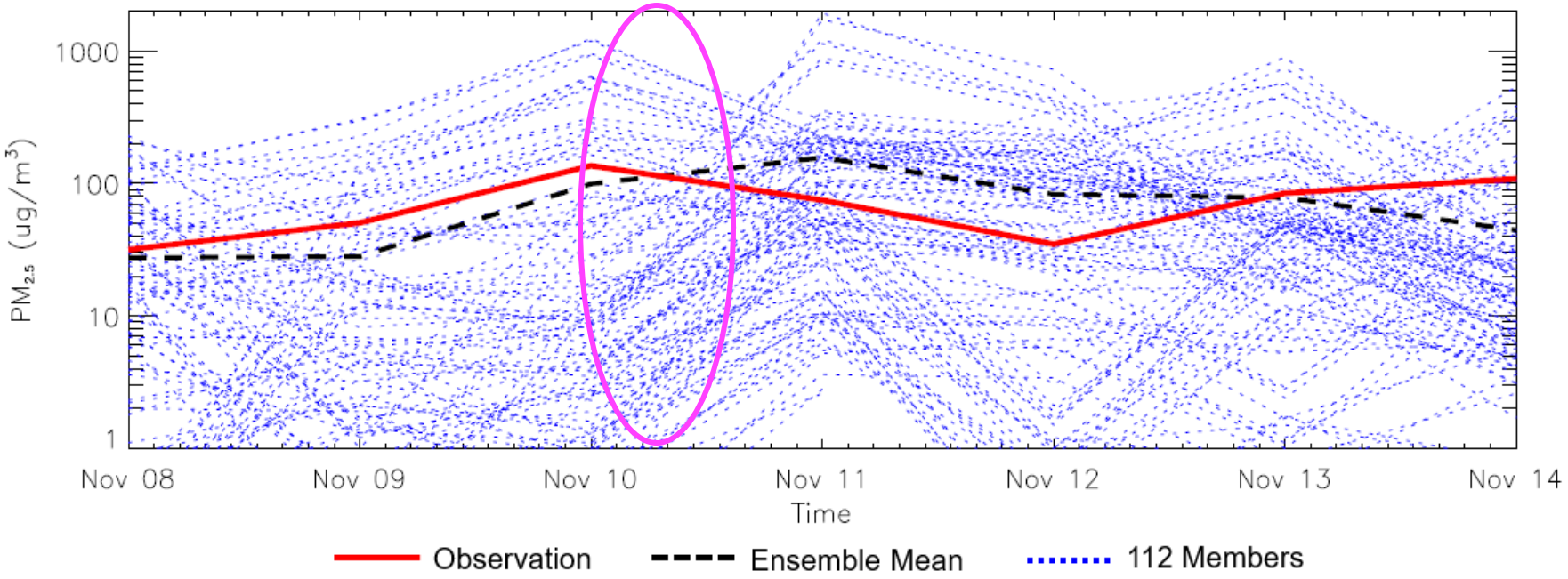
Hmmm, which product should we use???

GEFS: Global Ensemble Forecast System Aerosols; **NAQFC**: National Air Quality Forecasting Capability; **HRRR-Smoke**: NOAA High-Resolution Rapid Refresh-Smoke; **NAAPS**: Navy Aerosol Analysis and Prediction System; **GEOS**: Goddard Earth Observing System

Single Model Ensemble Forecast

- 112 simulations with NOAA **HYSPLIT** model at 0.1-degree.

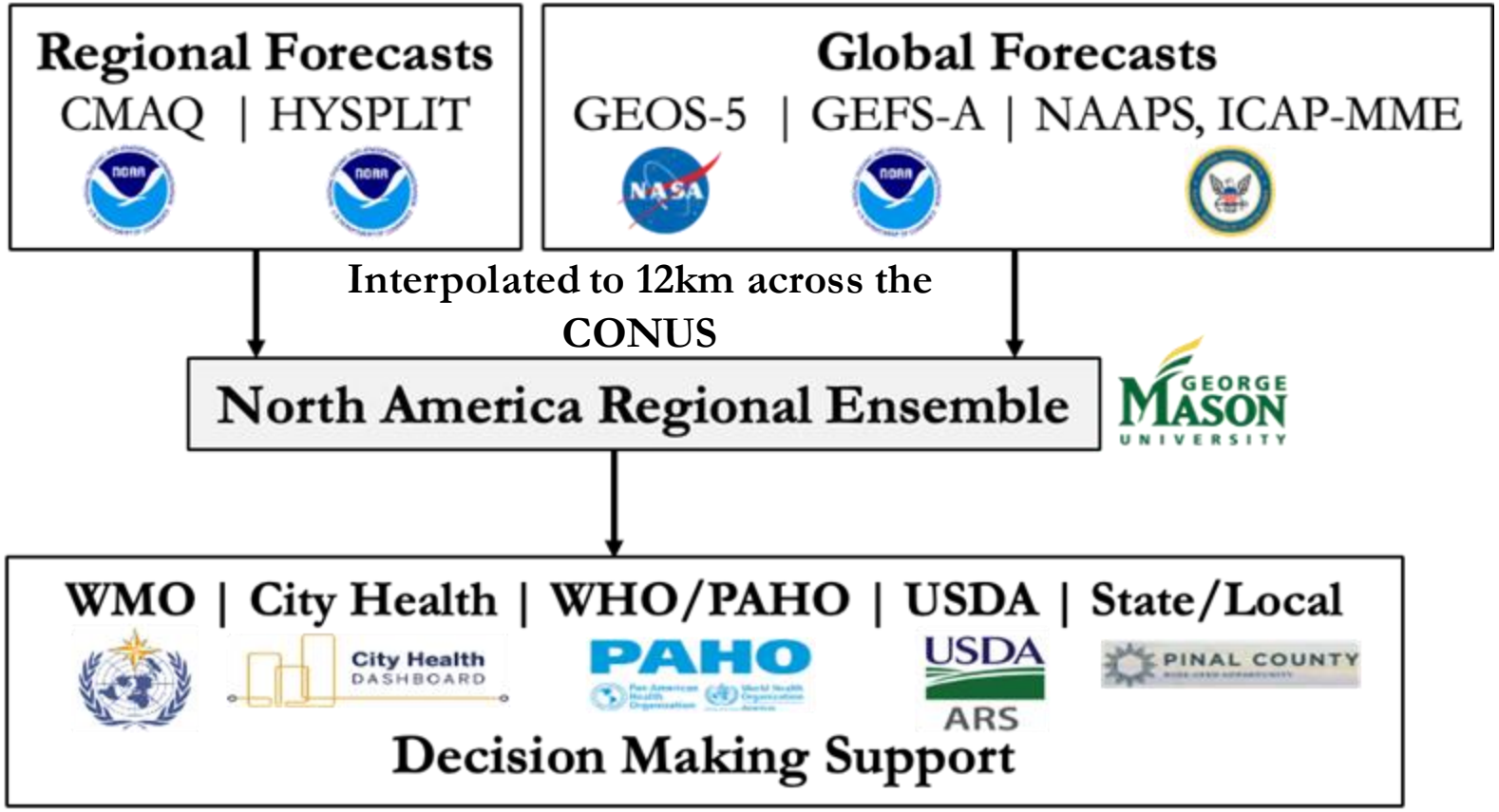




- Large ensemble spread
- Ensemble showing best performance

(Li et al., JGR-A, 2020)

Hazardous Air Quality Ensemble System (HAQES)

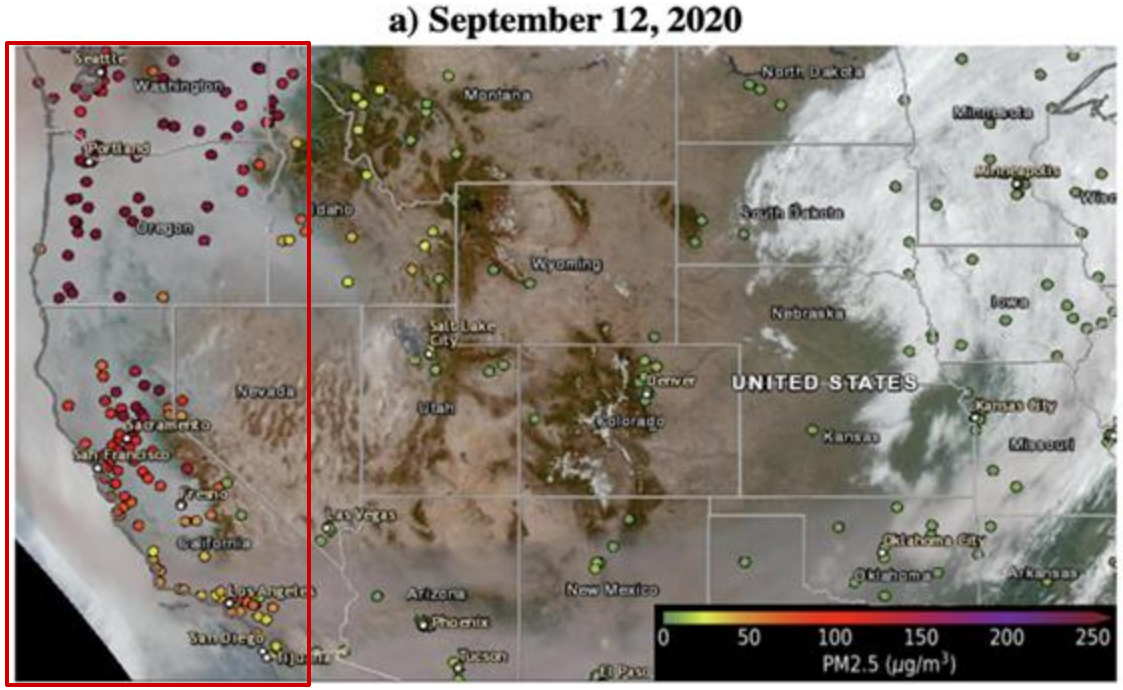


CMAQ: Community Multiscale Air Quality
HYSPLIT: Hybrid Single-Particle Lagrangian Integrated Trajectory
GEFS-A: Global Ensemble Forecast System Aerosols
GEOS: NASA Goddard Earth Observing System
ICAP-MME: International Cooperative for Aerosol Prediction Multi-Model aerosol forecasting Ensemble
NAAPS: Navy Aerosol Analysis and Prediction System

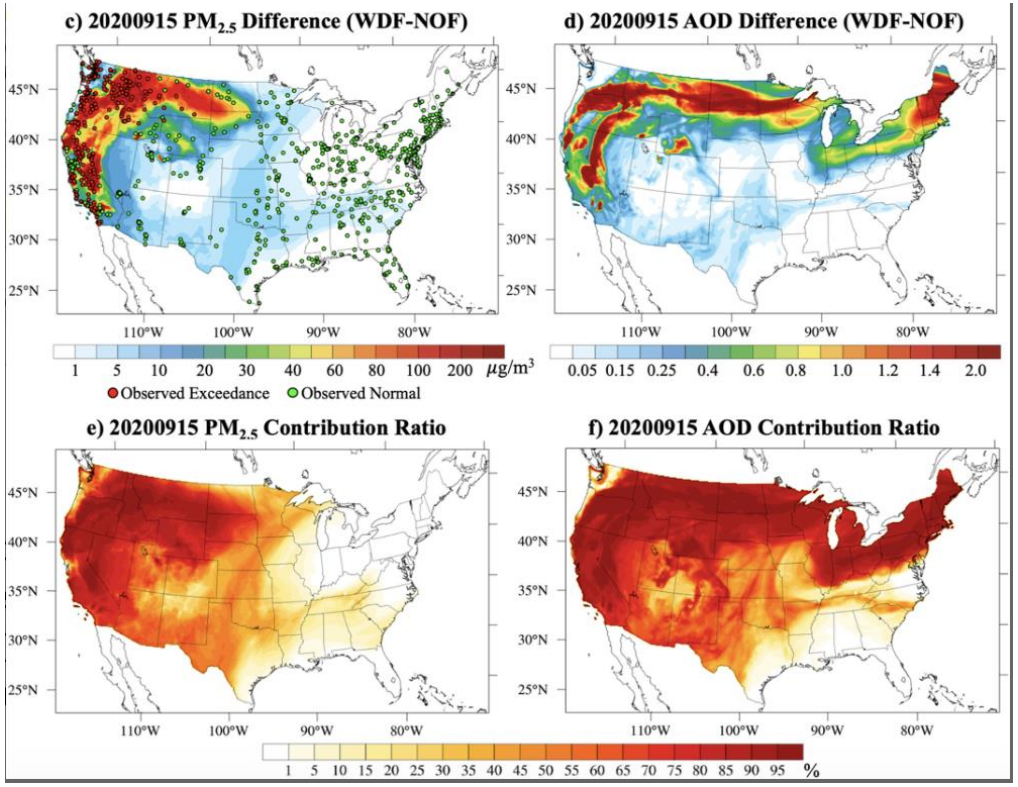
Ensemble Forecast for the 2020 "Gigafire"

The 2020 Gigafire events in the Western U.S. (August-September 2020)

- Since August 16th, many large fires contributed to the August Complex fire burning > 1 million acres in California.
- Wildfires were the primary contributor to the 3,720 observed exceedances.

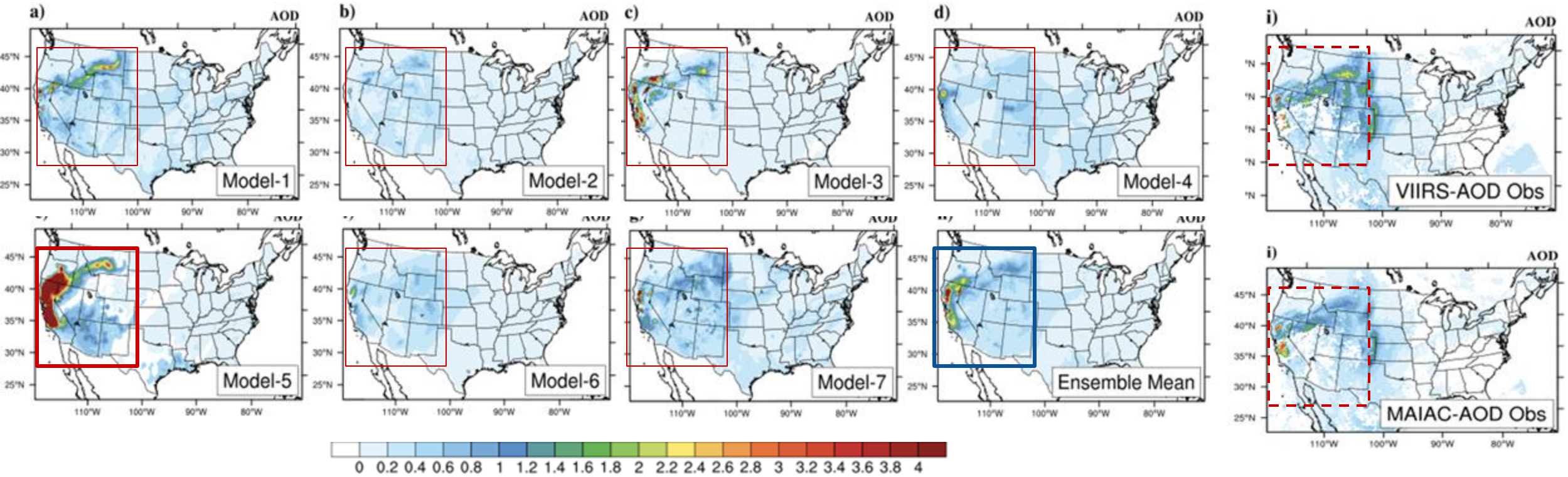


VIIRS/SNPP true color overlaid by AQS $PM_{2.5}$ (circles) (source: NOAA AerosolWatch)



(Li et al, GRL, 2021)

AOD Simulations vs. VIIRS and MAIAC AOD

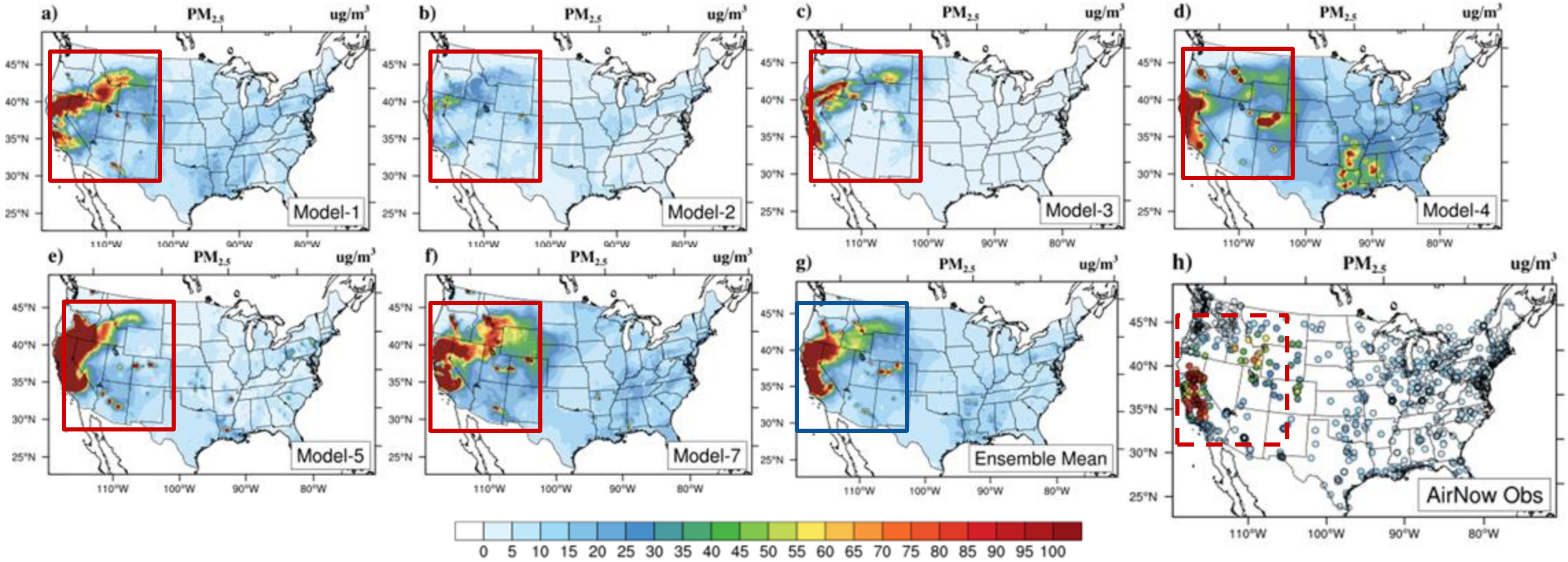


AOD predicted by seven individual models (a-g) and the ensemble mean (h), compared with VIIRS Dark Target (DT) and MAIAC AOD retrievals (i) for Aug 22nd, 2020.

- Most models underestimated AOD in CA and downwind regions except Model-5.
- The ensemble forecast matched the VIIRS and MAIAC AOD the most.

Note: Gaps in VIIRS and MAIAC AOD observations are missing data after quality control. (Makkaroon et al, JGR, 2023)

Simulated $PM_{2.5}$ vs. AirNow $PM_{2.5}$



Surface $PM_{2.5}$ predicted by six individual models (a-f) and the ensemble mean (g), compared with surface AirNow $PM_{2.5}$ (h).

- Individual models overestimated $PM_{2.5}$ largely in the western US and partially in the Central US (except Model-2)
- **Ensemble forecast** matched the AirNow $PM_{2.5}$ observations the most.

(Makkaroon et al, JGR, 2023)

$PM_{2.5}$ Forecasts vs. AirNow $PM_{2.5}$

Best performer in **bold**

Models	*RMSE*	*CORR*	*MB*	*FB*	*aH*(%)	*aFAR*(%)	*RANK*
Model-1	25.6	0.5	**3.4**	0.5	69.1	44.3	2.81
Model-2	**17.0**	0.5	-4.9	0.6	39.7	**23.7**	2.74
Model-3	21.0	0.4	-4.7	1.3	71.7	45.4	2.40
Model-4	52.0	0.5	19.8	0.9	79.2	75.6	2.38
Model-5	52.0	0.4	13.0	0.8	81.0	68.7	2.50
Model-7	40.0	0.5	12.3	0.7	80.789	62.5	2.63
Ensemble Mean	26.0	**0.6**	7.4	**0.5**	**87.0**	60.5	**2.83**

- The ensemble performs the best with strongest correlation, best *FB*, highest aH, and the best *RANK*.

(Makkaroon et al, JGR, 2023)

Ensemble Probability Forecast of $PM_{2.5}$ Exceedances

Ensemble provides probabilistic forecasts of health-based $PM_{2.5}$ exceedances (>35 μg/m^3).

Six Members: GMU-CMAQ, NACC-CMAQ, GEFS-Aerosols, GEOS-5, HYSPLIT, and NAAPS.

P(A) = Number of models that forecast the exceedances/ Total number of models

(Very Likely to Occur)

100% : **All models** forecast the exceedances

83%

67%

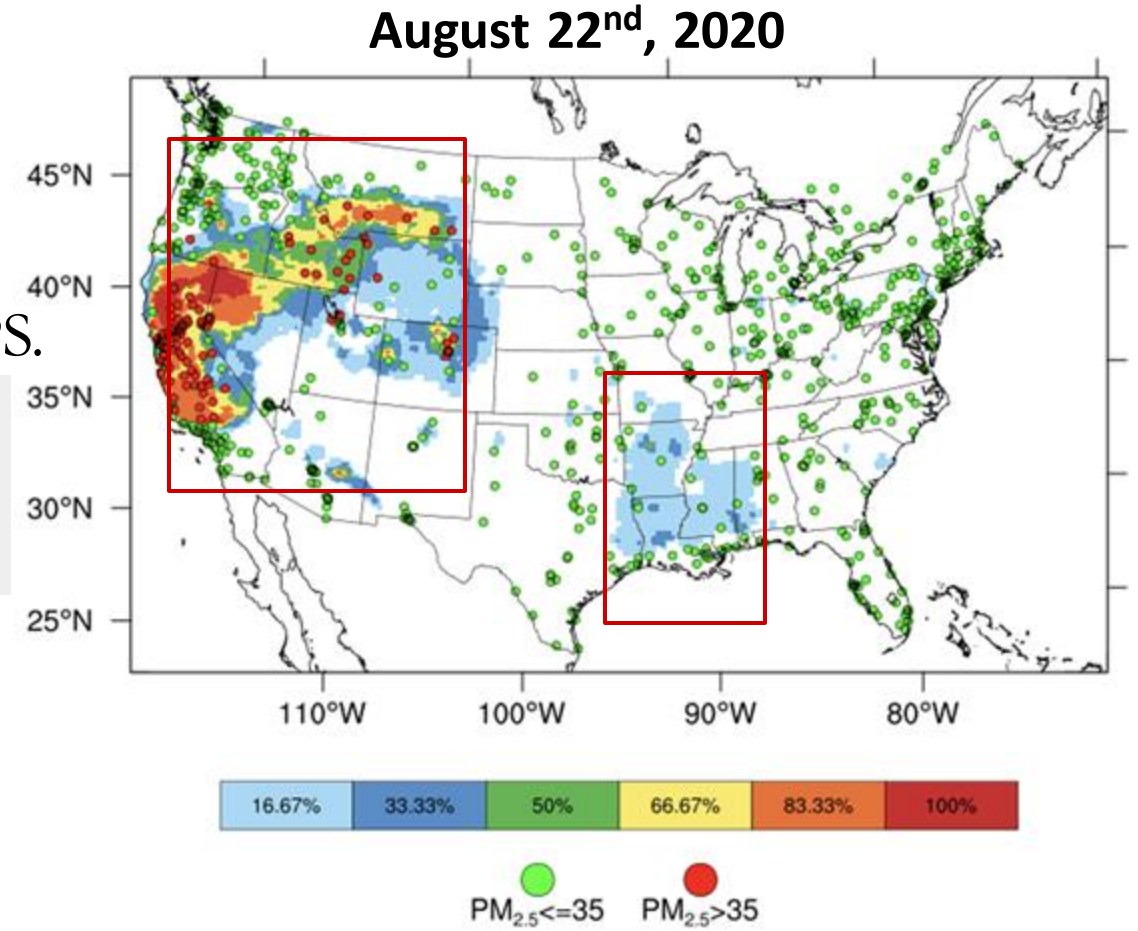
50%

33%

17%

0% : **None of models** forecast the exceedances

(Very Unlikely to Occur)



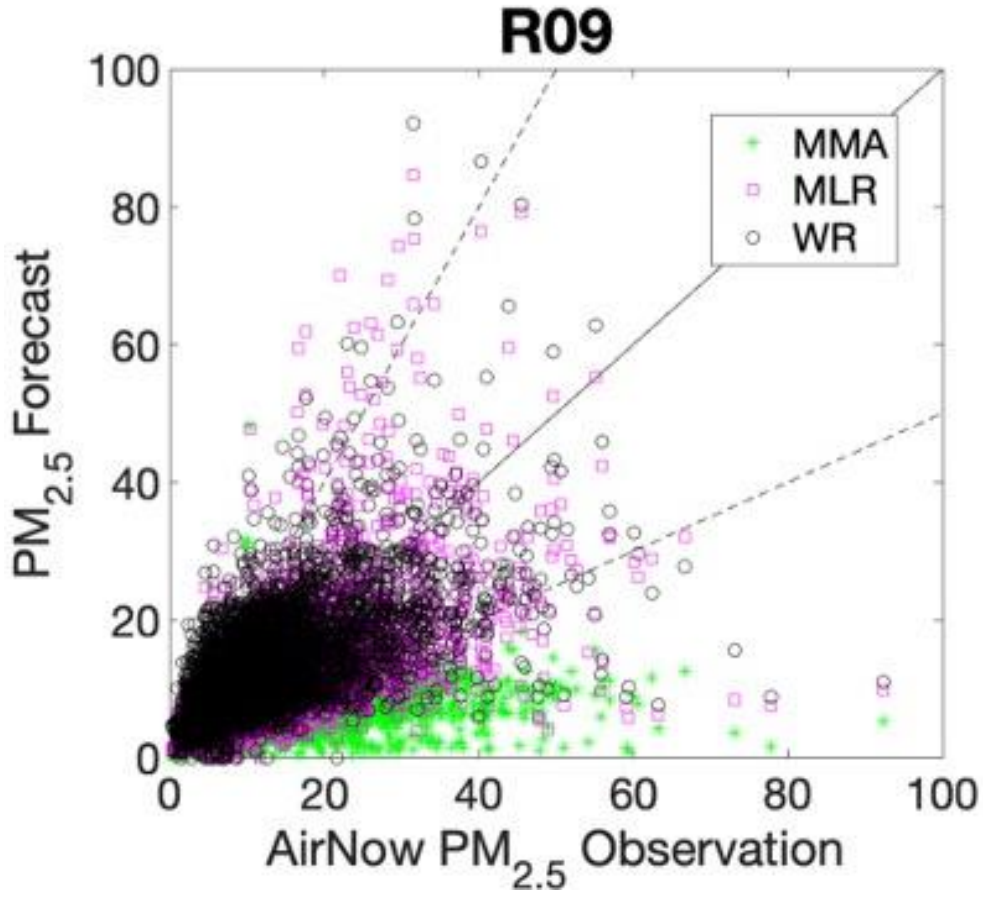
- **High exceedance probability values (83%-100%)** were predicted in CA and MT.
- False exceedances predicted in LA, MS, and AR (17%)

Multi-Model Average (Unweighted) vs Weighted Ensemble

Weighing Approaches

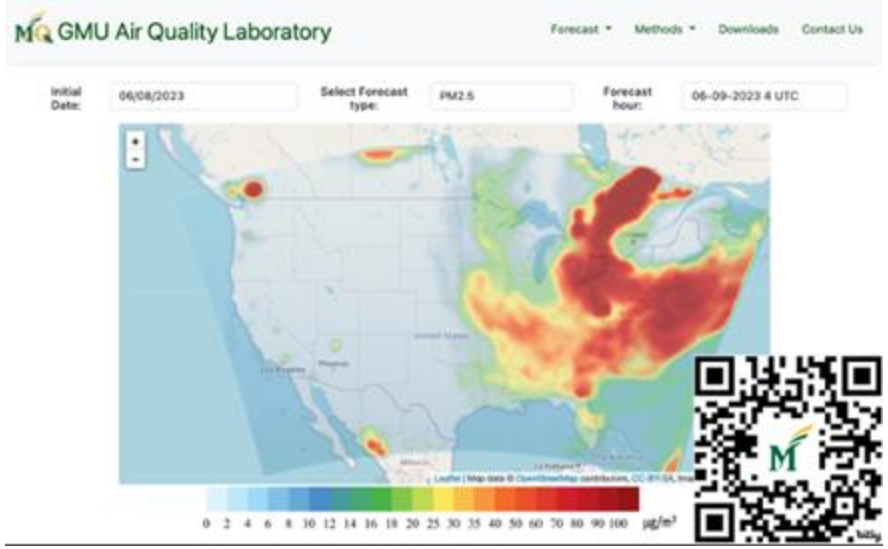
1. Multi-linear Regression (MLR)
2. Ridge Regression (RR)
3. Quantile Regression (QR)
4. Weighted Regression (WR)

	MMA	MLR	QR	WR
Bias ($\mu g/m^3$)	0.5	0.3	0.4	0.3
Hit Rate (%)	56	65	87	70
False Alarm (%)	29	8	33	15



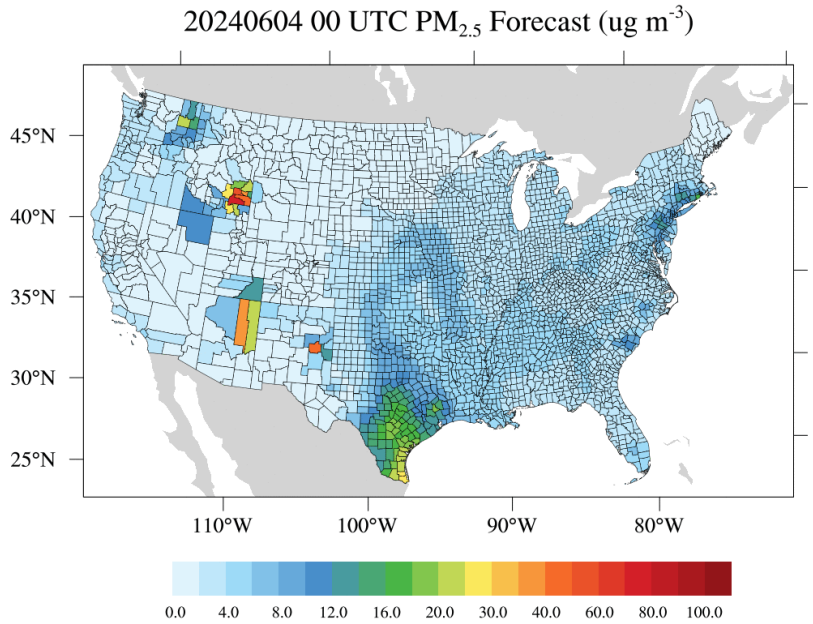
(Li et al, BAMS, 2024)

HAQES Data Access

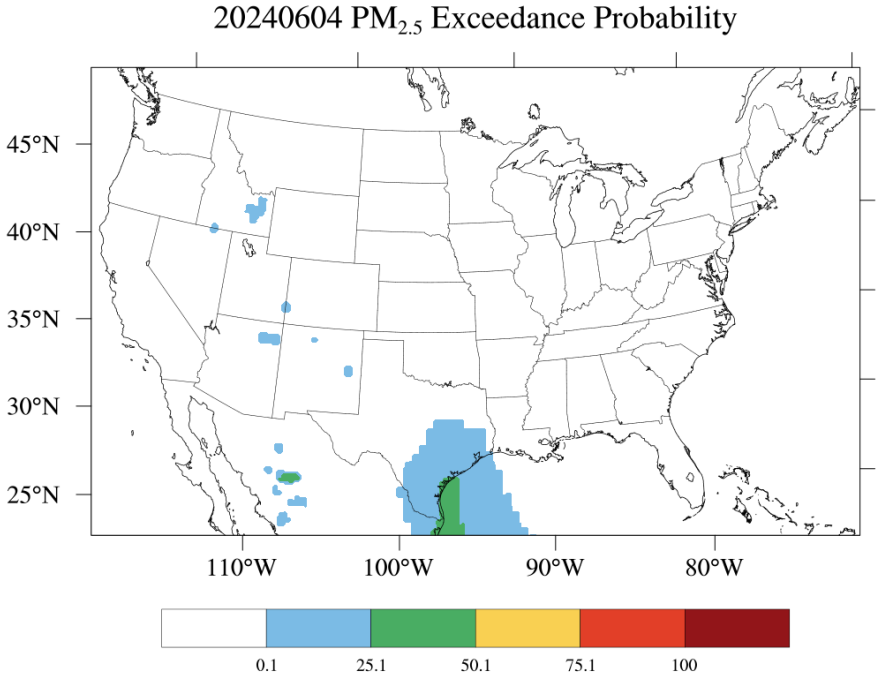


- Wildfire $PM_{2.5}$, OC, EC, AOD
- $PM_{2.5}$ Exceedance Probability
- netCDF and ASCII (County/Census Tract)
- Download data from NASA GES DISC (see Xiaohua Pan's Poster)

County-/Census-tract-level Forecasts



PM2.5 Exceedance Probability



Project website: http://air.csiss.gmu.edu/haqes/

Data access: https://disc.gsfc.nasa.gov/datasets/HAQES_NA_PM25_OC_COUNTY_1/summary