THE UNIVERSITY OF IOWA

Support Air Quality and Public Health Management in Wildfires: Satellite and Machine Learning Based $PM_{2.5}$ Forecast

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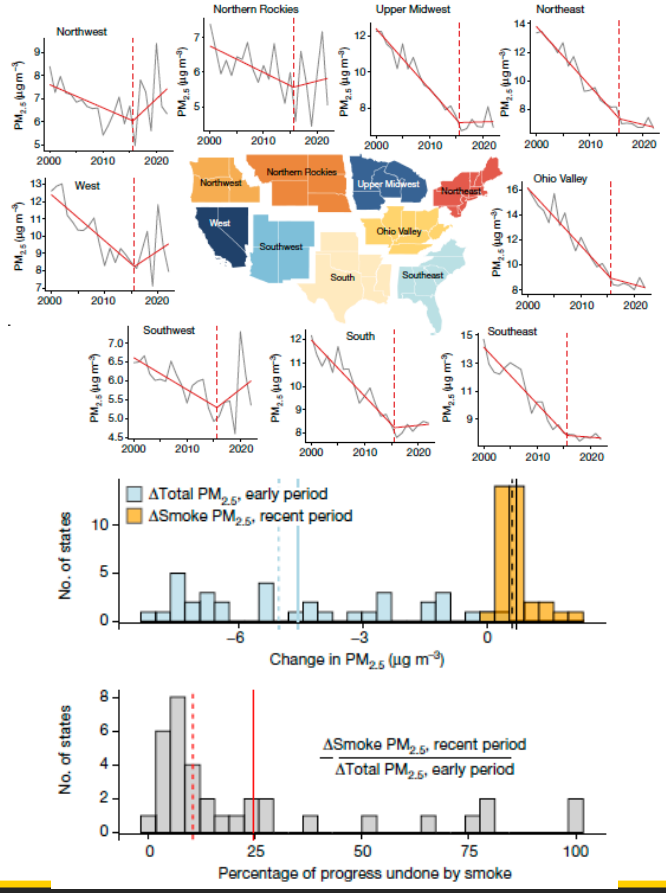
NASA

WASHINGTON UNIVERSITY IN ST. LOUIS 1853

Wildfire smoke influences CONUS $PM_{2.5}$ pollution

Erode multi-decadal progress in reducing $PM_{2.5}$ pollution

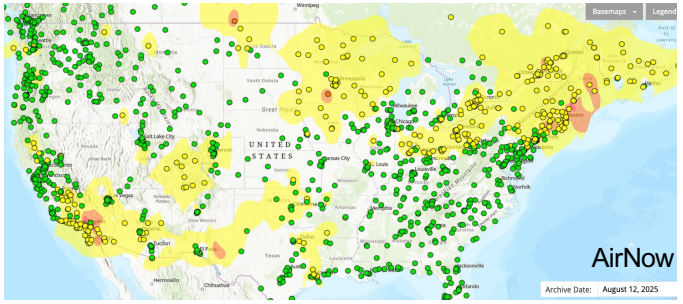
- **Smoke reverse/stagnate $PM_{2.5}$ trend in most states:**



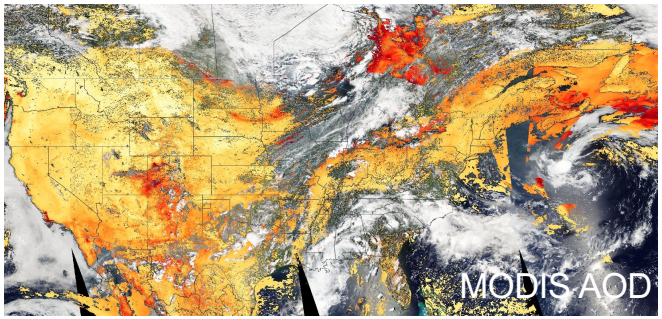
Wildfire smoke erodes ~25% of previous multi-decadal progress in reducing $PM_{2.5}$ in ¾ states, even > 50% in western states.

(Burke, M. et al., 2023, Nature)

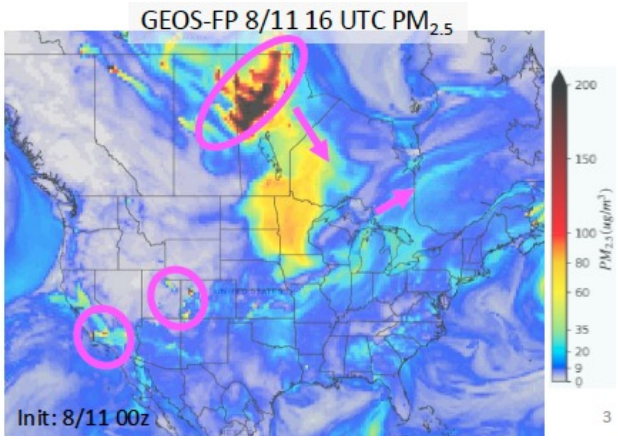
- **$PM_{2.5}$ monitoring and forecasting:**



Ground measurements



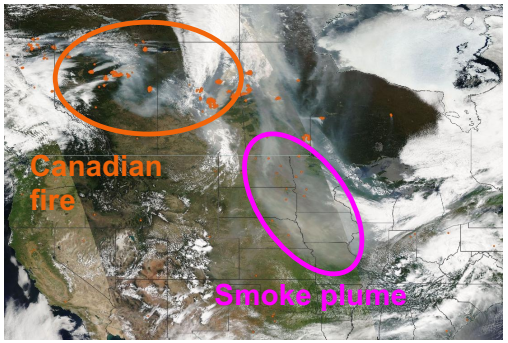
Satellite observations



CTM forecasts

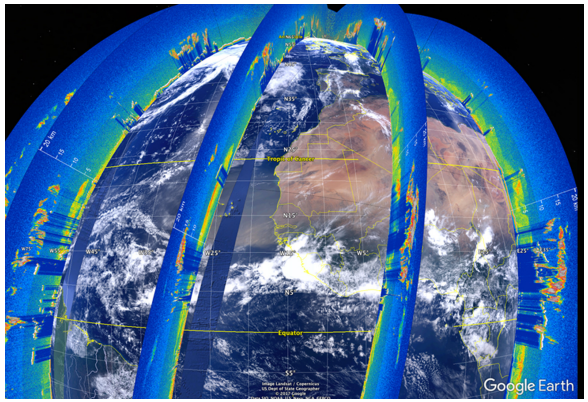
Challenges of $PM_{2.5}$ forecast under smoke

Uncertainty in smoke plume vertical distribution



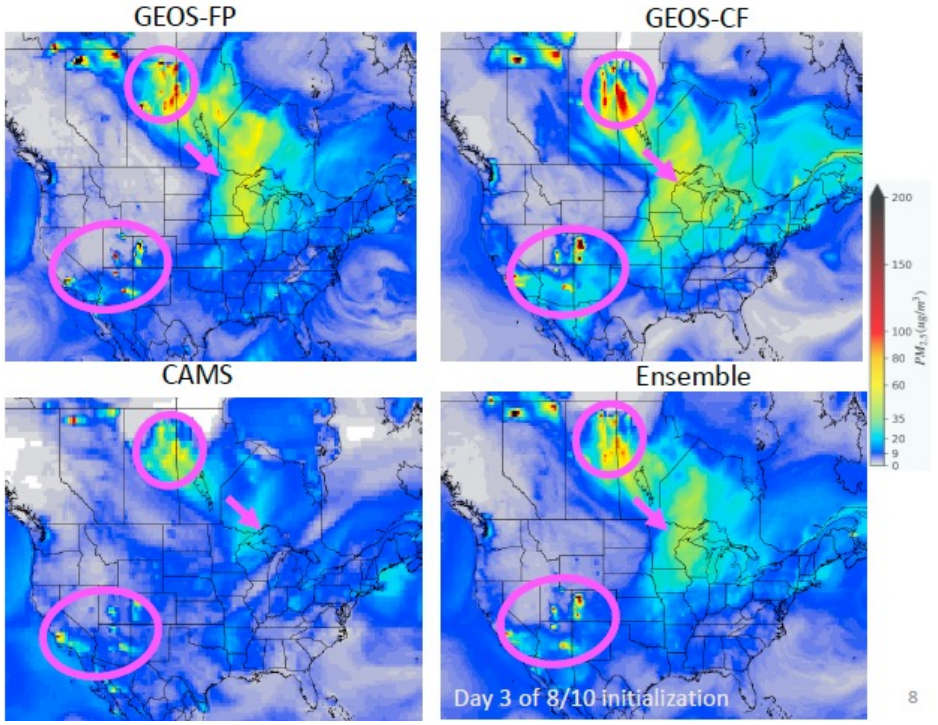
Total column amount (AOD)
Vertical distribution
→ Surface $PM_{2.5}$ concentration

- **Limited spatial coverage from lidars:**



< 0.2% globe

- **Discrepancies in various CTMs:**

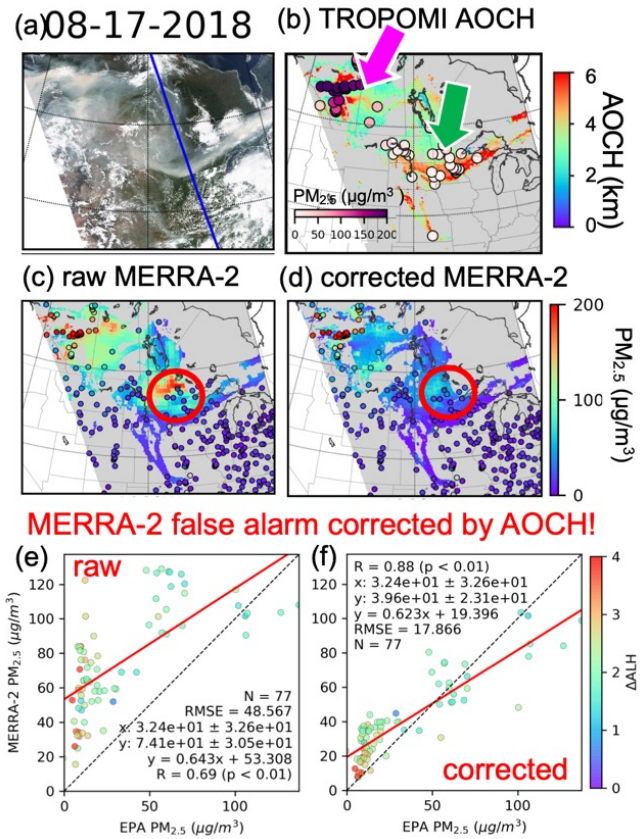


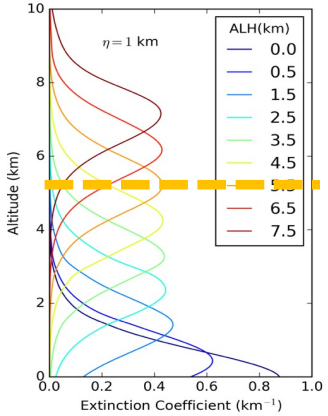
Different representation of smoke plume vertical distribution and injection heights in CTMs.

New passive satellite AOCH measurements

From EPIC, TROPOMI to TEMPO with high temporal and spatial resolution

- **Aerosol optical centroid height (AOCH):**





AOCH

(Chen. et al., 2021, RSE)

- **Multiple passive satellite AOCH measurements:**

Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

TROPOMI (global, daily)

First retrieval of absorbing aerosol height over dark target using TROPOMI oxygen B band: Algorithm development and application for surface particulate matter estimates

Xi Chen[a,b,*], Jun Wang[a,b,c,*], Xiaoguang Xu[d], Meng Zhou[b,c], Huanxin Zhang[a,b], Lorena Castro Garcia[a,b], Peter R. Colarco[e], Scott J. Janz[e], John Yorks[e], Matthew McGill[e], Jeffrey S. Reid[f], Martin de Graaf[g], Shobha Kondragunta[h]

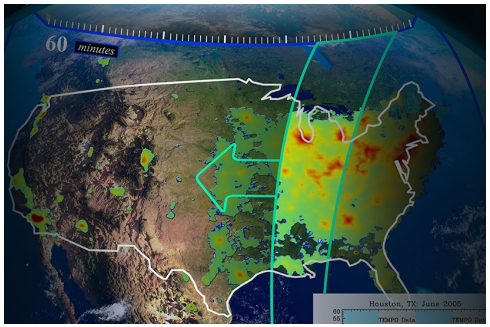
Atmospheric Measurement Techniques

EPIC/DSCOVR (global, ~1.5 hourly)

Detecting layer height of smoke aerosols over vegetated land and water surfaces via oxygen absorption bands: hourly results from EPIC/DSCOVR in deep space

Xiaoguang Xu[1,2], Jun Wang[1], Yi Wang[1], Jing Zeng[1], Omar Torres[3], Jeffrey S. Reid[4], Steven D. Miller[5], J. Vanderlei Martins[2], and Lorraine A. Remer[2]

TEMPO (CONUS, hourly)

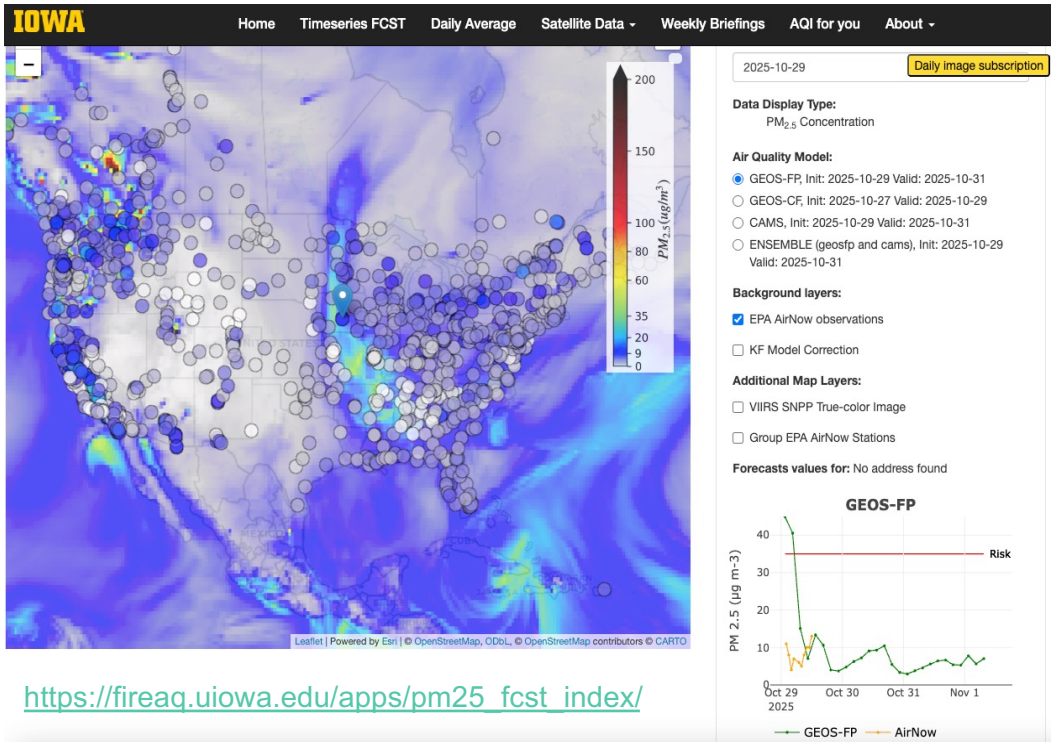


We have made efforts to develop our own AOCH product using O_2 A and B bands.

FireAQ: Monitoring Fire and Air Quality Forecasts

A decision support system under smoke combining NRT measurements and CTM

- **$PM_{2.5}$ monitoring (AirNow) and forecasts (CTMs):**

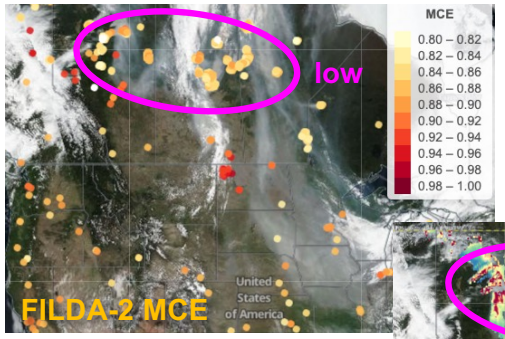


https://fireaq.uiowa.edu/apps/pm25_fcst_index/

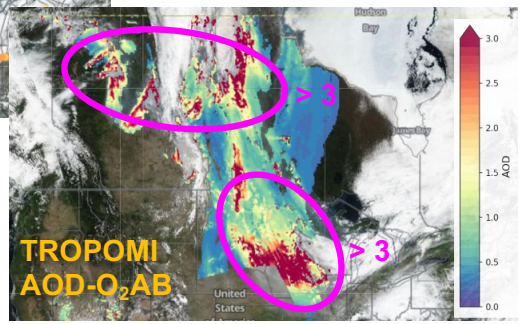
(Supported by NASA's HAQ2021 program)

Host weekly meetings during fire seasons engaged with stakeholders to analyze the exceptional wildfire smoke events and predict their influence on $PM_{2.5}$ in CONUS.

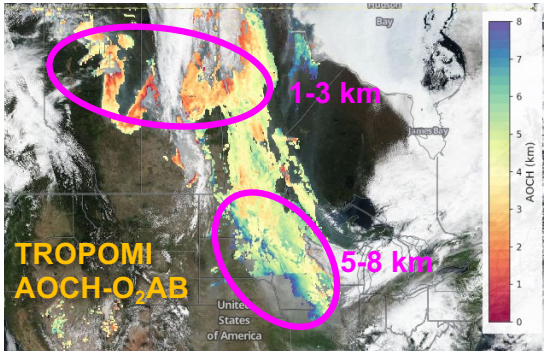
- **NRT satellite measurements:**



Fire locations, MCE, VEF, FRP



TROPOMI AOD from O_2AB algorithm: Smoke plume transport



TROPOMI AOCH from O_2AB algorithm: Smoke plume ascend during transport

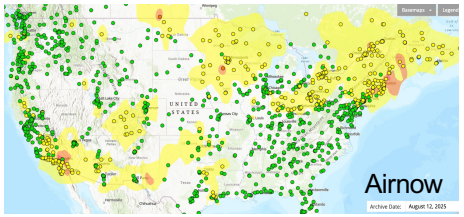
Objectives

To extend the capability of FireAQ in supporting decision-making activities relying on $PM_{2.5}$ forecast, **this project has three key objectives**:

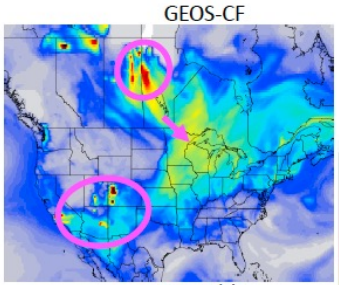
- Develop hourly TEMPO UVAI, AOCH and AOD for wildfire smoke in CONUS and validate them by newly launched EarthCARE lidar and ground-based lidars like MPLNET. Visualization of TEMPO products on FireAQ system will also be conducted.

- Use state-of-the-art ML tool to forecast gapless surface $PM_{2.5}$ distribution over CONUS in near real time, considering satellite AOCH measurements under smoke conditions. **This will be the first attempt to apply satellite AOCH in surface $PM_{2.5}$ forecast**.

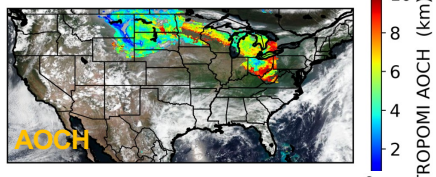
- In collaboration with stakeholders, evaluate the performance of TEMPO AOCH and ML $PM_{2.5}$ forecast in decision-making activities relevant to smoke pollution by analyzing exceptional wildfire events.

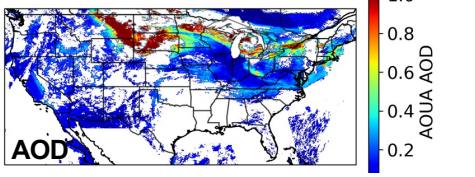


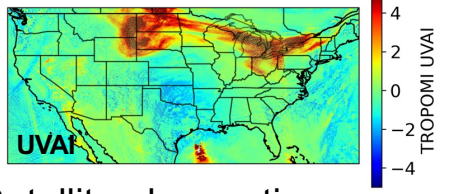
Ground measurements



CTM forecasts

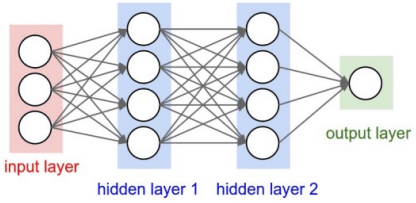






Satellite observations

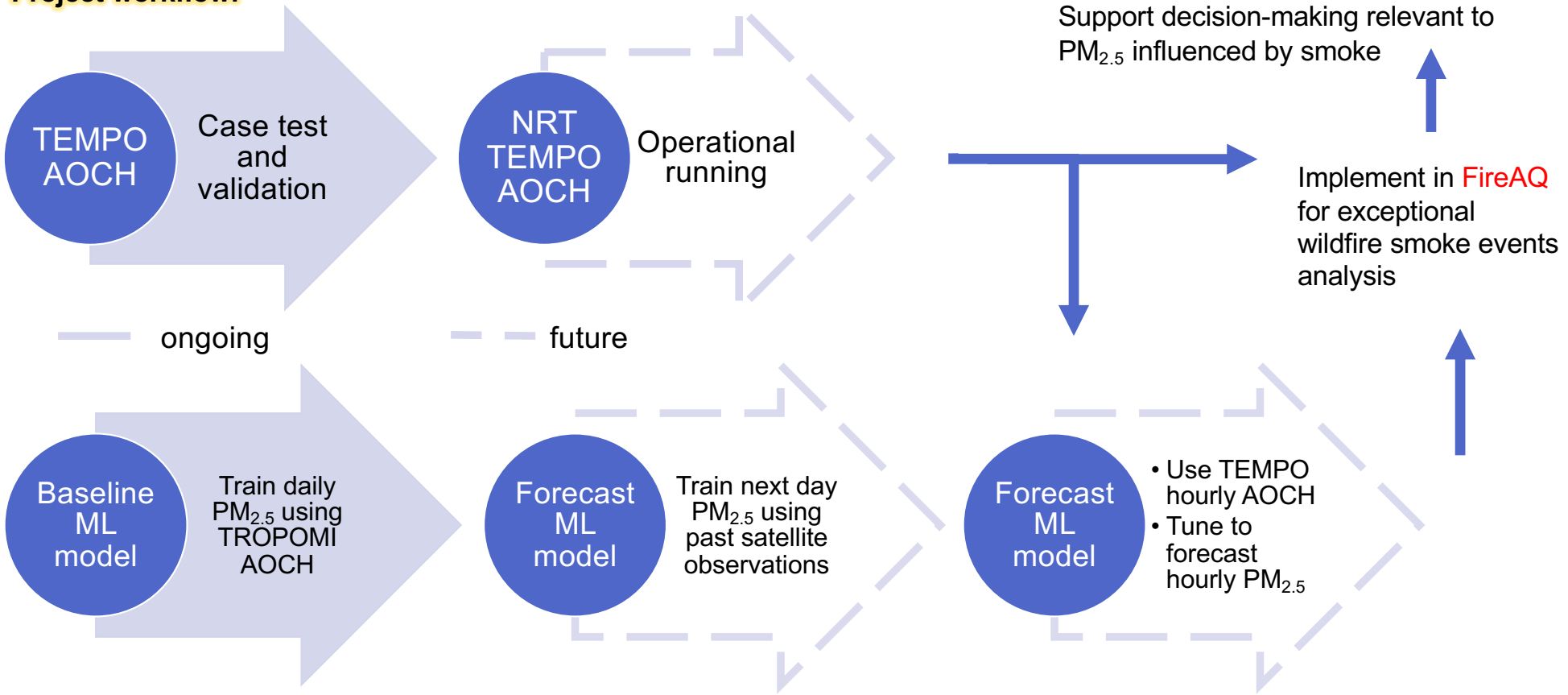
Machine learning models



NRT observations and $PM_{2.5}$ forecast

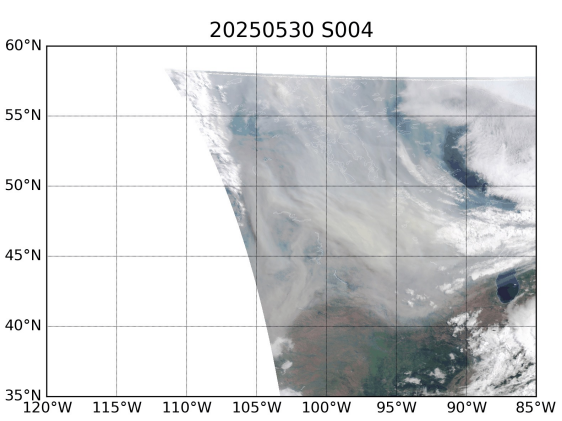
TEMPO NRT AOCH and forecast ML model

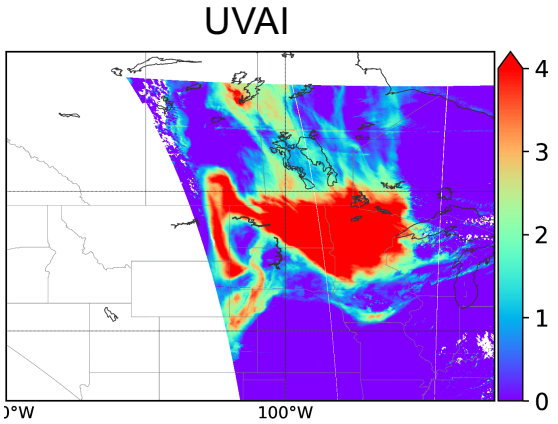
- **Project workflow:**



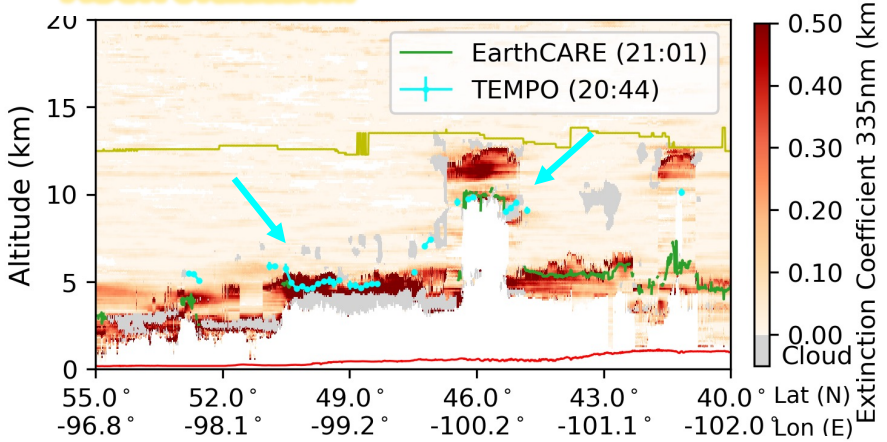
TEMPO AOCH development from O_2 B band

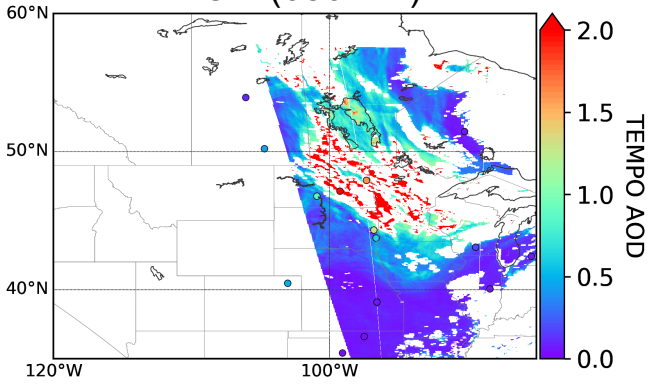
Merge O_2 AB algorithm to TEMPO O_2 B band getting good AOCH retrieval

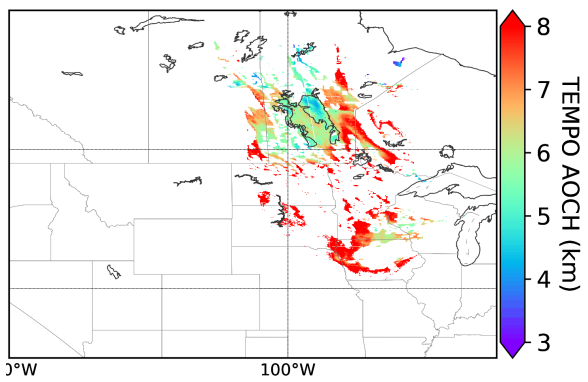




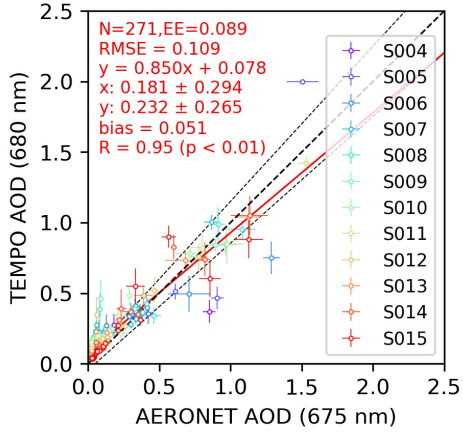
- **AOCH evaluation:**





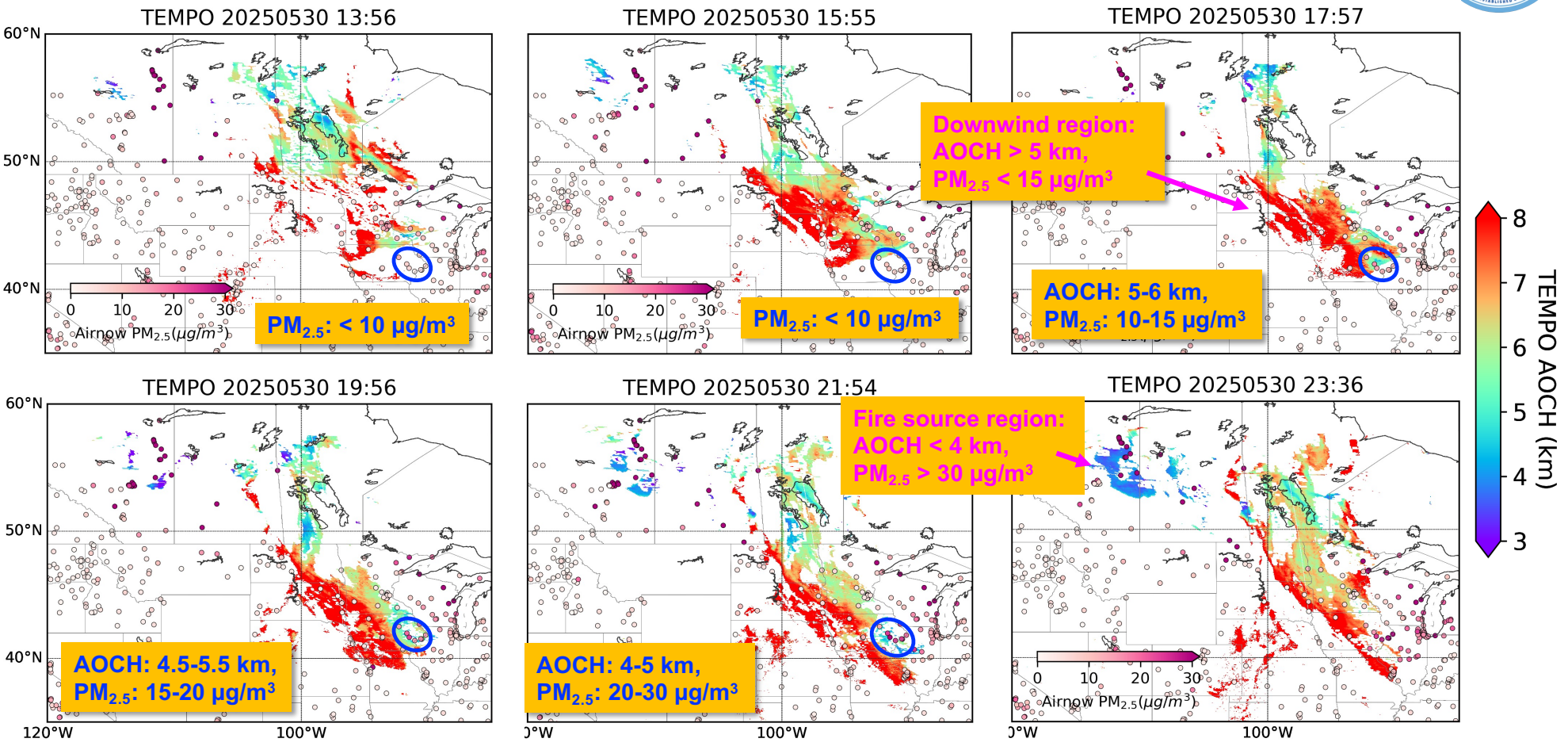


- **AOD validation:**



Diurnal variation of AOCH and $PM_{2.5}$

Descending of smoke plume enhances $PM_{2.5}$ pollution



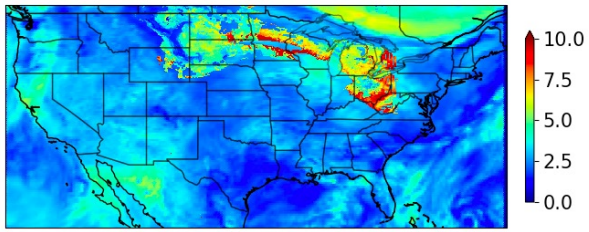
ML based $PM_{2.5}$ estimates

Use satellite aerosol products and model meteorology

- **Features:**

Data source	Parameters	Spatial resolution
GEOS-FP (or ERA5)	surface wind, PBLH, surface air temperature, total precipitation, specific humidity, surface pressure	0.3125°×0.25° (or 0.1°×0.1° for ERA5)
GEOS-CF	surface $PM_{2.5}$	0.25°×0.25°
TROPOMI	UVAI, AOCH (combined with GEOS-FP AOCH), AOCH source mask	0.05°×0.05°
MODIS	MAIAC AOD (combined with GEOS-FP AOD), AOD source mask, NDVI	1 km

Combined AOCH (km)



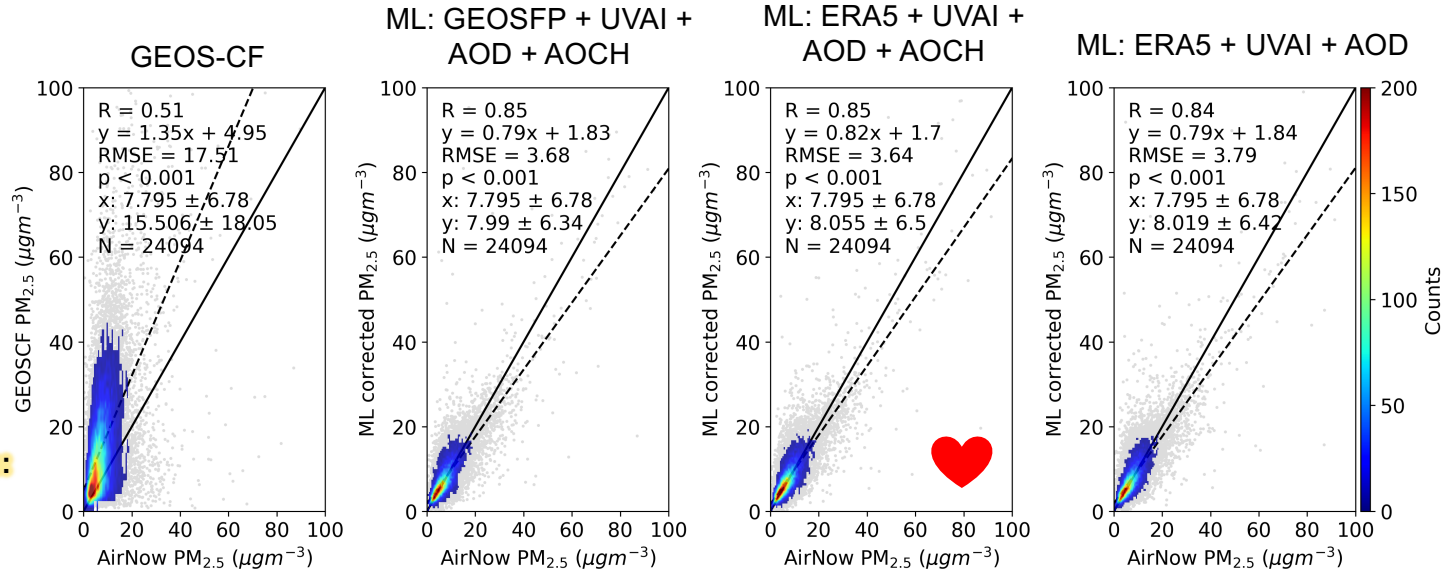
- **Targets:**

  AirNow $PM_{2.5}$ (daily or hourly)
  Data period: 2022-2024

- **Model:**

  Multi-layer perceptron (MLP)

- **Test data evaluation:**



Looking forward for more progress!

Acknowledgement