Satellite-Assisted Particulate Matter (SAPM) for the Models, In situ, and Remote sensing of Aerosols (MIRA) Working Group

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Travis D. Toth[1] (travis.d.toth@nasa.gov), Greg L. Schuster[1], Alexander Matus[2], Mian Chin[2], Meloë Kacenelenbogen[2], Edward Nowottnick[2], Melanie Follette-Cook[2], and Karn Vohra[3]

[1]NASA Langley Research Center, Hampton, VA USA [2]NASA Goddard Space Flight Center, Greenbelt, MD USA [3]University College London, U.K.

1. What is MIRA?

- A forum that fosters international collaborations amongst the aerosol Modeling, In situ, and Remote sensing specialties
- A collection of interdisciplinary and independently funded projects/topics with clear goals
- Projects/topics are generally characterized by requests for additional scientific data (both observational and modeled)

- Purpose: to contextualize both observations and model results through encouragement of holistic projects and collaborations

MIRA webpage: https://science.larc.nasa.gov/mira-wg/

Sign up for MIRA emails at: https://espo.nasa.gov/lists/listinfo/mira/

2. The SAPM Topic Group

- Fine particulate matter ($PM_{2.5}$) is a major contributor to air pollution and negatively impacts human health
- SAPM aims to provide intercomparisons of various methods and techniques for retrieving surface $PM_{2.5}$ assisted by satellite remote sensors, global aerosol models, and *in situ* aerosol measurements
- Overall motivation of our work: enhance $PM_{2.5}$ coverage beyond *in situ* ground stations

Approach	Strengths	Weaknesses
Spaceborne lidar (active sensor)	-Aerosol vertical structure in the column and presence/absence of near-surface aerosols -Daytime & Nighttime measurements	-Spatial and temporal coverage are sparse -Longer latency, so near-real time (NRT) is difficult
Spaceborne radiometer (passive sensor)	-Spatial and temporal coverage -City level trends	-No nighttime data available -Only column-integrated aerosol view; no vertical structure
Aerosol Model	-Spatial and temporal coverage -NRT analysis/products	-Uncertainties in emissions & aerosol speciation -Skill in relating AOD to $PM_{2.5}$ & capability of accurate representation of aerosol vertical profiles

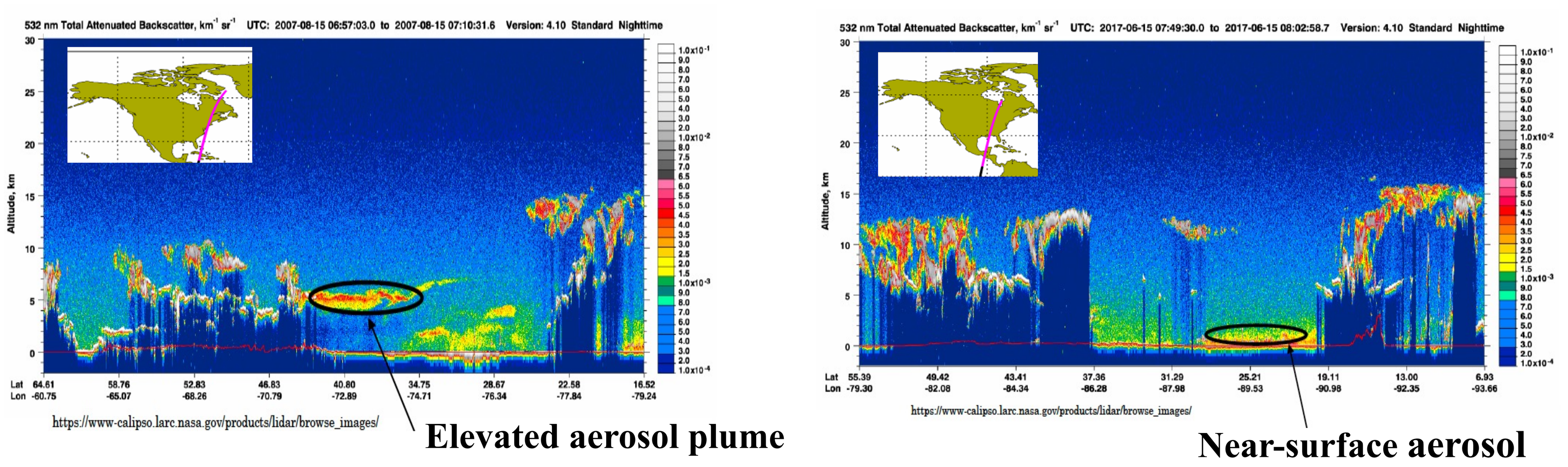
Request for international datasets

- To improve/validate the $PM_{2.5}$ estimates, the SAPM Topic Group seeks international *in situ* datasets of:
  - **Mass scattering/absorption coefficient and aerosol hygroscopic properties for various aerosol species**
  - **Ground-based $PM_{2.5}$ concentrations**

SAPM webpage: https://science.larc.nasa.gov/mira-wg/projects/sapm/

3. Estimating $PM_{2.5}$ using mainly spaceborne lidar

CALIOP curtain plots (https://www-calipso.larc.nasa.gov/products/lidar/browse_images/production/)



Unlike column-integrated aerosol optical thickness (AOT) from passive sensors, lidars provide aerosol vertical distribution, including aerosol extinction near the ground (a more realistic representation of near-surface aerosol properties)

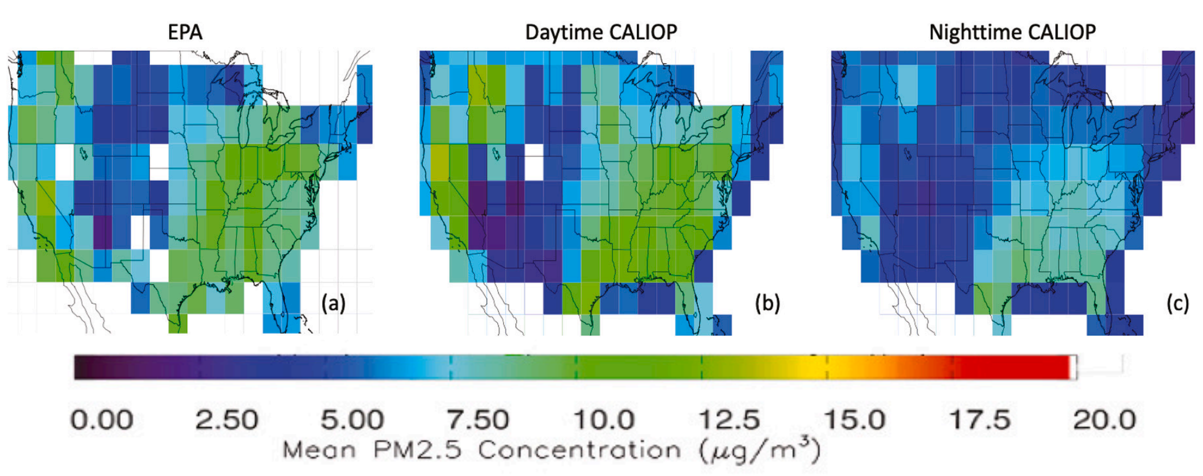
$PM_{2.5}$ derivation algorithm (using CALIOP aerosol extinction & assumed mass extinction efficiency):

$$PM_{2.5} = \frac{\sigma \times \varphi \times 1000}{(\alpha_{scat} \times f_{rh} + \alpha_{abs})}$$

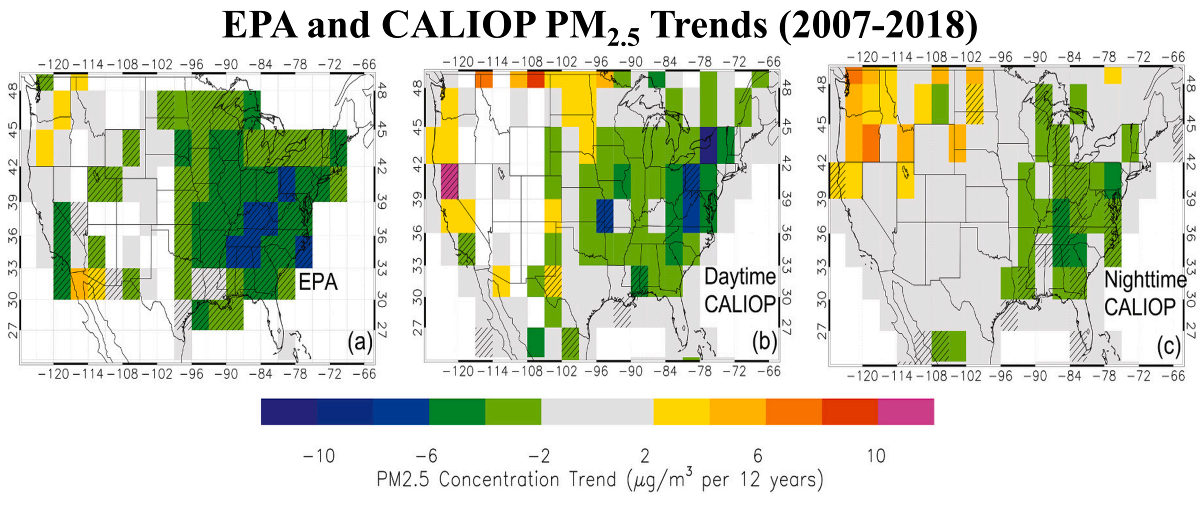
Hygroscopic growth factor $$f_{rh} = \left(\frac{1-RH}{1-RHref}\right)^{-\Gamma}$$

- ***$PM_{2.5}$*** → $PM_{2.5}$ mass concentration (μg m^{-3})
- ***α_{scat}*** → mass scattering efficiency (**3.40** $m^2 g^{-1}$)
- ***α_{abs}*** → mass absorption efficiency (**0.37** $m^2 g^{-1}$)
- ***φ*** → $PM_{2.5}$ to PM_{10} ratio (**0.6**)
- ***σ*** → extinction coefficient (m^{-1})
- ***1000*** → unit conversion factor

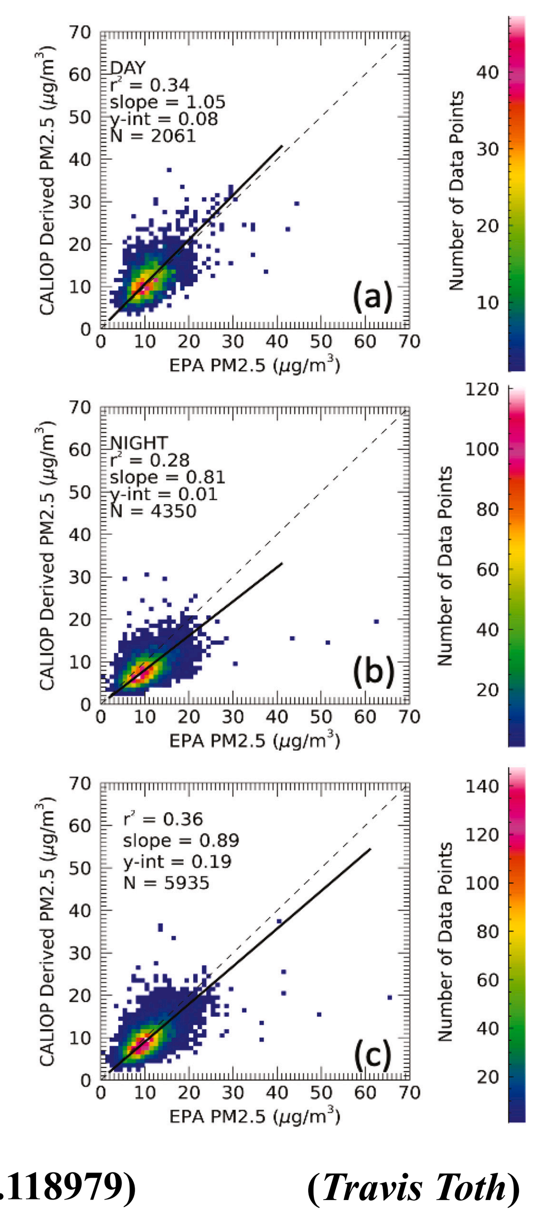
Spatial Mean $PM_{2.5}$ from EPA and CALIPSO (2007-2018)



EPA and CALIOP $PM_{2.5}$ Trends (2007-2018)



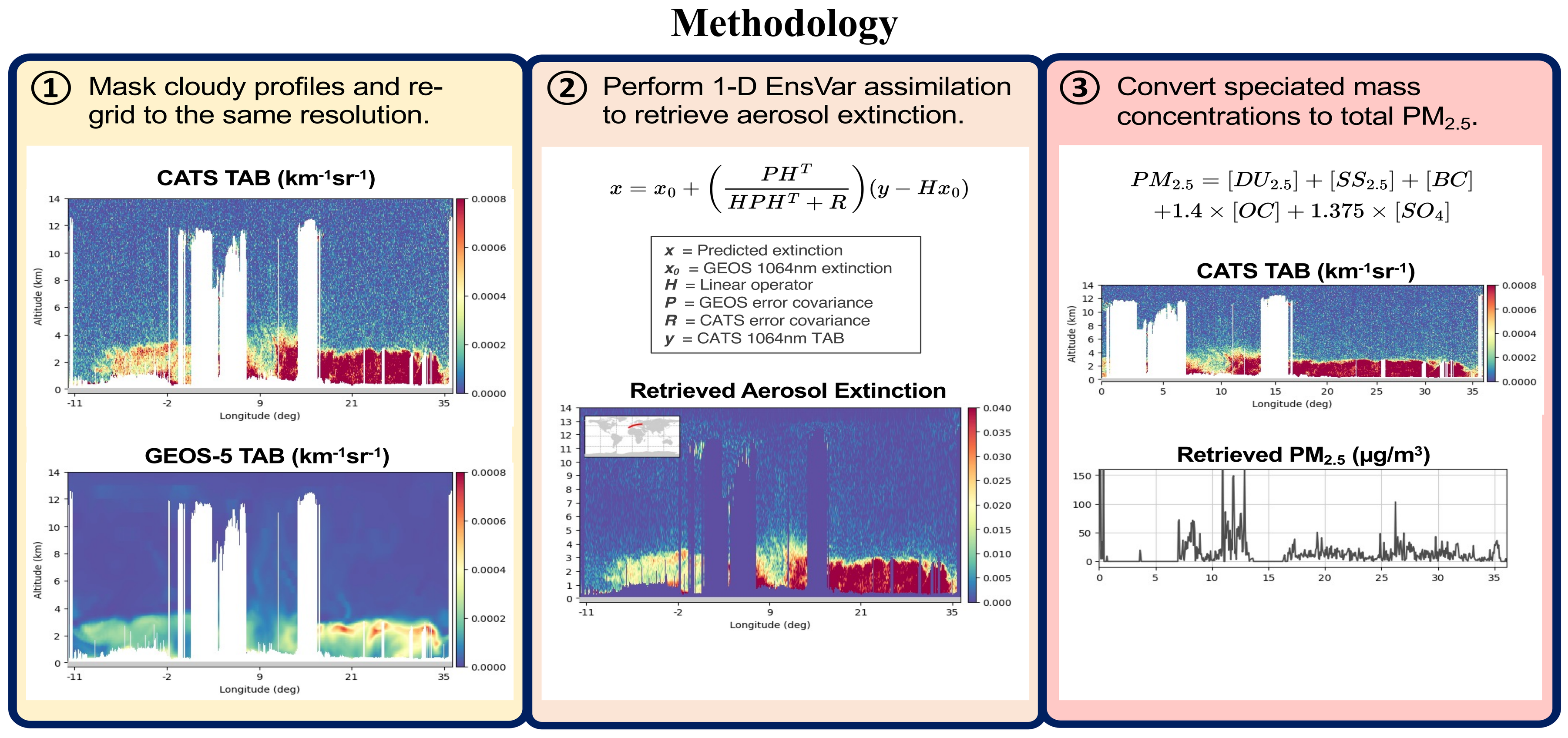
Initial Validation Efforts



(*Toth et al.*, 2022, Atmos. Env., https://doi.org/10.1016/j.atmosenv.2022.118979) (*Travis Toth*)

4. Estimating $PM_{2.5}$ using spaceborne lidar + model

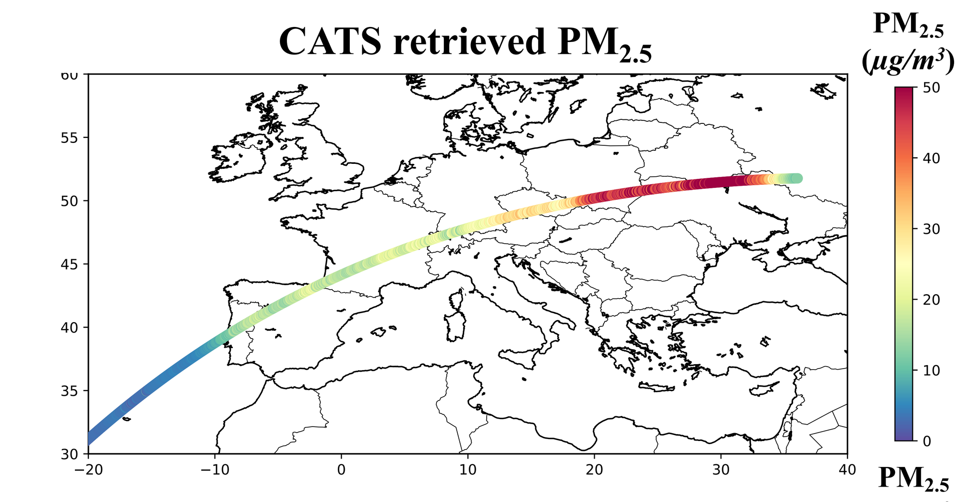
Methodology



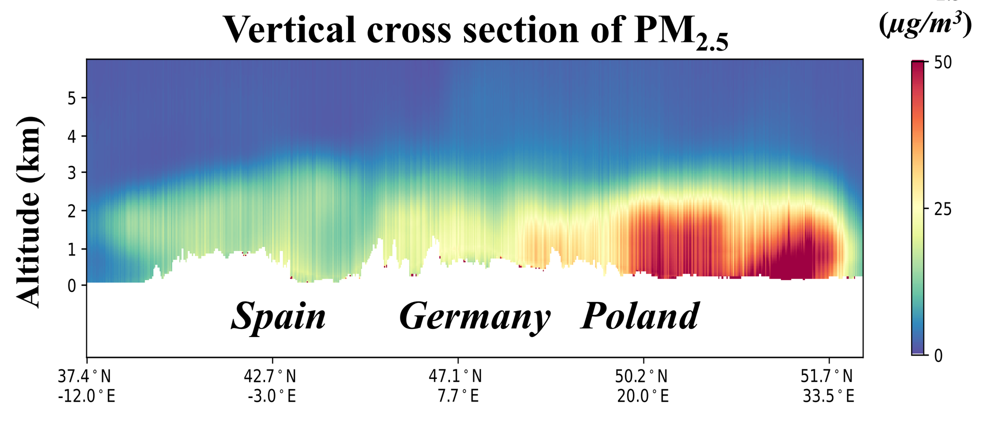
TAB = Total Attenuated Backscatter

---Case study over Europe on 12 Sep 2016---

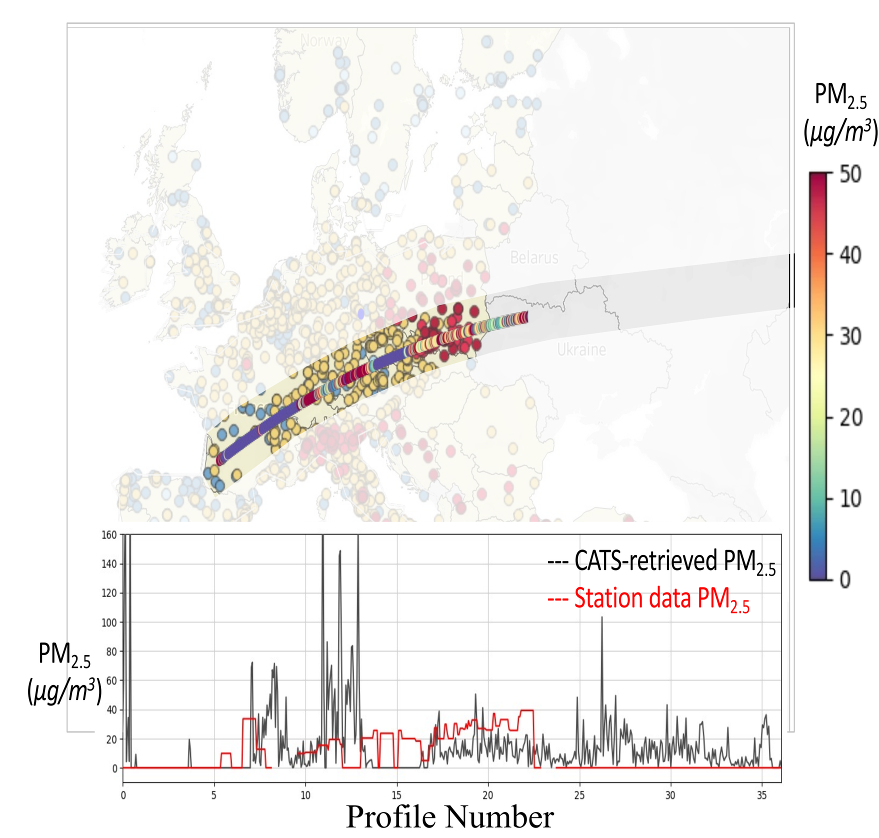
CATS retrieved $PM_{2.5}$



Vertical cross section of $PM_{2.5}$



Initial Validation Efforts



("New approach for $PM_{2.5}$ air quality retrievals using the NASA CATS spaceborne lidar and GEOS-5 model", *Matus et al.*, in prep.) (*Alex Matus*)

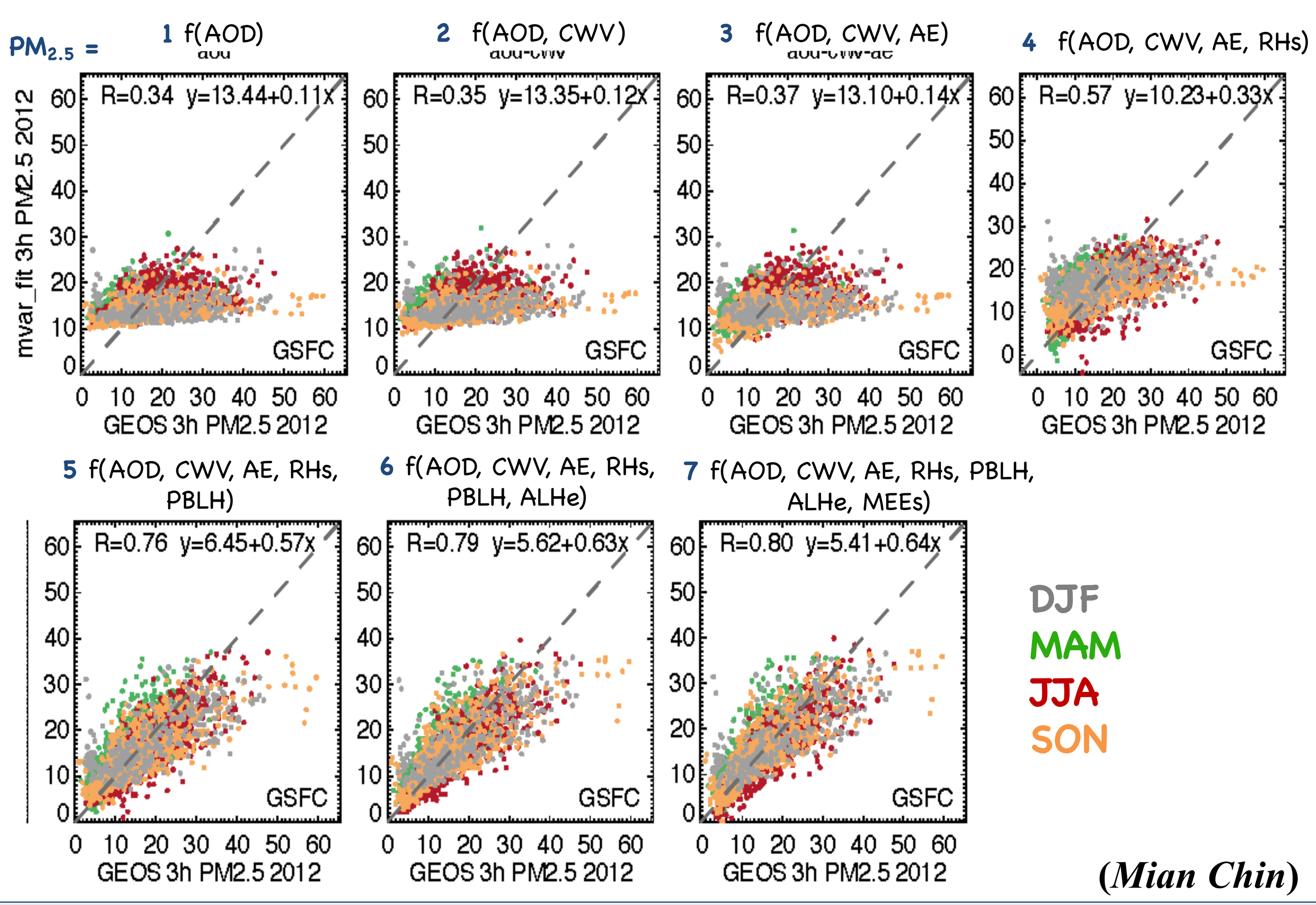
5. Studying $PM_{2.5}$ using GEOS (global aerosol model)

Estimated $PM_{2.5}$ from multivariate regression vs. "true" GEOS-calculated $PM_{2.5}$ at a US site (2012; GSFC, MD)

We select several key "observable" variables from the GEOS model for multi-variable regression to estimate the 3-hourly $PM_{2.5}$ concentrations from model simulated AOD and compare them to the "true" model calculated $PM_{2.5}$ values:

1 – Aerosol optical depth (AOD)
2 - Column water vapor (CWV)
3 - Angstrom Exponent (AE)
4 - Surface RH (RHs)
5 - PBL Height (PBLH)
6 - Aerosol effective layer height (ALHe)
7 - Surface mass extinction efficiency (MEEs)

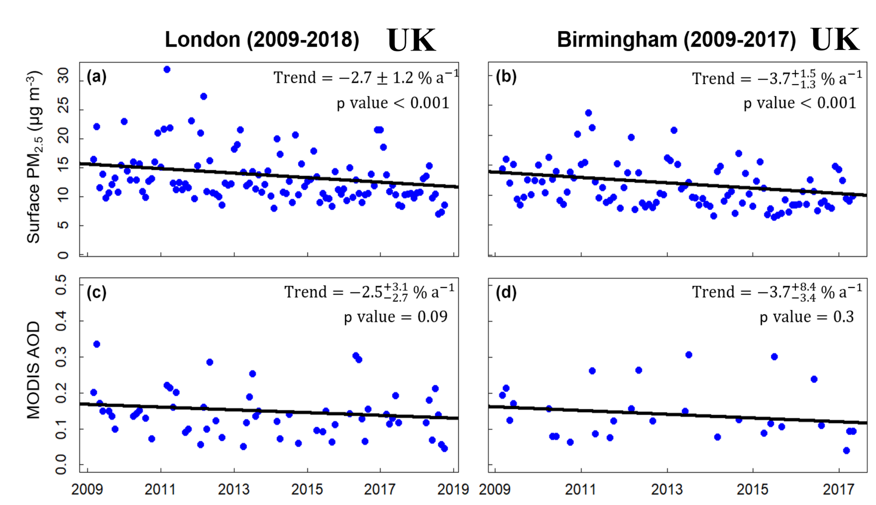
Including the 6 additional parameters in estimating surface $PM_{2.5}$ from AOD can deliver much improved results



(*Mian Chin*)

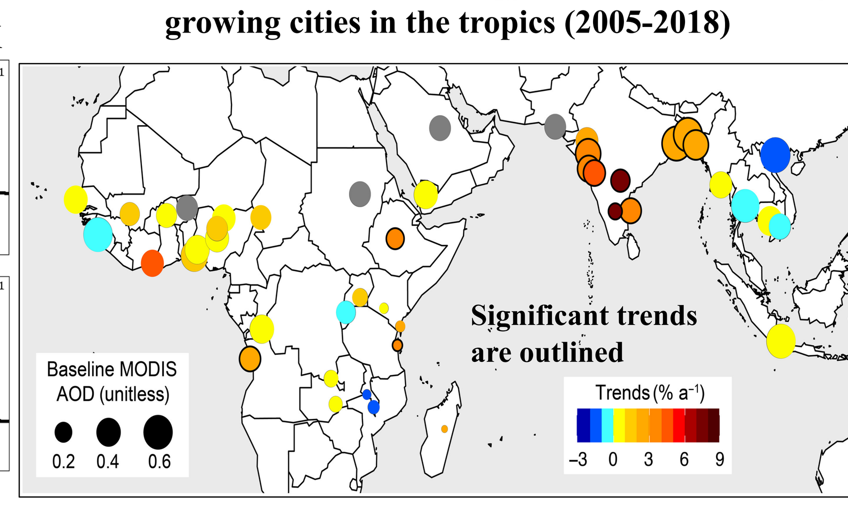
6. Exploring City Trends in $PM_{2.5}$ using MODIS AOD (spaceborne passive sensor)

Time series of monthly surface $PM_{2.5}$ and MODIS AOD



(*Vohra et al.*, 2021, ACP, https://doi.org/10.5194/acp-21-6275-2021)

AOD trends as proxies for $PM_{2.5}$ abundance in rapidly growing cities in the tropics (2005-2018)



(*Vohra et al.*, 2022, Sci. Adv., https://doi.org/10.1126/sciadv.abm4435)

City AOD trends agree well with trends in city surface $PM_{2.5}$, providing confidence in use of city AOD for city $PM_{2.5}$ trend studies

Steep and significant trends in AOD are found for several South Asian cities, suggesting rapid growth in $PM_{2.5}$

(*Karn Vohra*)