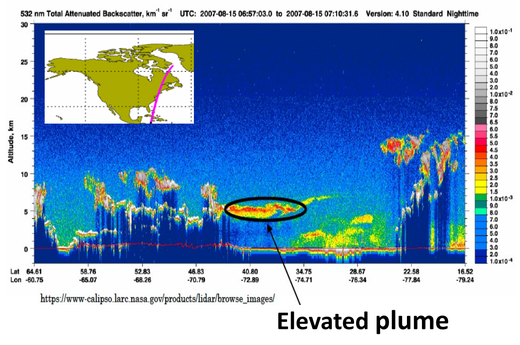
Retrieving CALIOP-based Particulate Matter Concentrations for the Models, In situ, and Remote sensing of Aerosols (MIRA) Project

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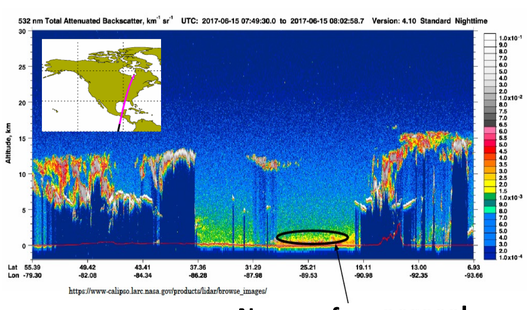
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1. Introduction and Motivation

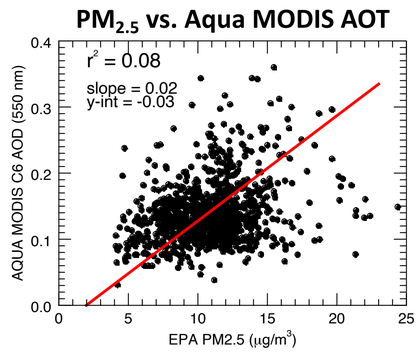
- $PM_{2.5}$ is a major contributor to air pollution and negatively impacts human health
- Past studies have estimated $PM_{2.5}$ concentrations from aerosol optical thickness (AOT) from passive satellite sensors (e.g., MODIS, MISR)
- **Limitations of this approach**:
  - $PM_{2.5}$ is surface-based, but AOT is column-integrated
  - AOT incorporates the effects of humidity, whereas $PM_{2.5}$ is a dry-mass measurement



Elevated plume



Near-surface aerosol



(2008-2009)

- CALIOP provides aerosol vertical distribution at both daytime and nighttime
- Unlike AOT, extinction near the ground is a more realistic representation of near-surface aerosol properties
- Investigate the use of CALIOP near-surface aerosol extinction for $PM_{2.5}$ applications through a bulk mass scattering scheme

2. Data, Methods, and Algorithm

Data

- Daily $PM_{2.5}$ Local Conditions from Environmental Protection Agency (EPA) ground stations (parameter code: 88101)
- Extinction coefficients (532 nm) from V4.10 CALIOP L2 5 km aerosol profile (L2_05kmAPro) product

Methods

- Twelve years (2007-2018) over the CONUS (day & night)
- CALIOP data quality-assured and cloud-screened
- Aerosol profiles linearly re-gridded from 60 m vertical resolution (AMSL) to 100 m, referenced to local surface (AGL)
- Mean surface extinction computed as the 100-1000 m AGL altitude range
- For validation purposes, EPA and CALIOP data spatially (within 100 km) and temporally (same day) collocated

Dry mass scattering (a_{scat}) and absorption (a_{abs}) efficiencies (m^2g^{-1})

- Dependent upon aerosol type (i.e., fine coarse partition of pollution/smoke vs. dust/sea salt)
- Dominant aerosol type over CONUS assumed to be pollution aerosol
- Excluded aerosol extinction range bins classified as dust
- Values used: a_{scat} = **3.4** m^2g^{-1} and a_{abs} = **0.37** m^2g^{-1} (Hess et al. 1998; Malm and Hand, 2007; Lynch et al. 2016; Kaku et al. 2018)

Hygroscopic growth factor (f_{rh})

- Surface PM concentrations are dry mass measurements
- To account for impact of humidity on a_{scat}
- **RH** obtained from MERRA-2 reanalysis (included in CALIPSO files)

$$1 \quad C_m = \frac{\beta}{a}$$

$$2 \quad a = a_{scat} + a_{abs}$$

$$3 \quad C_m = \frac{\beta}{(a_{scat} + a_{abs})}$$

$$4 \quad f_{rh} = \left(\frac{1-RH}{1-RHref}\right)^{-\Gamma}$$ **Hygroscopic growth factor**

$$5 \quad C_m = \frac{\beta}{(a_{scat} \times f_{rh} + a_{abs})}$$

Final equation:

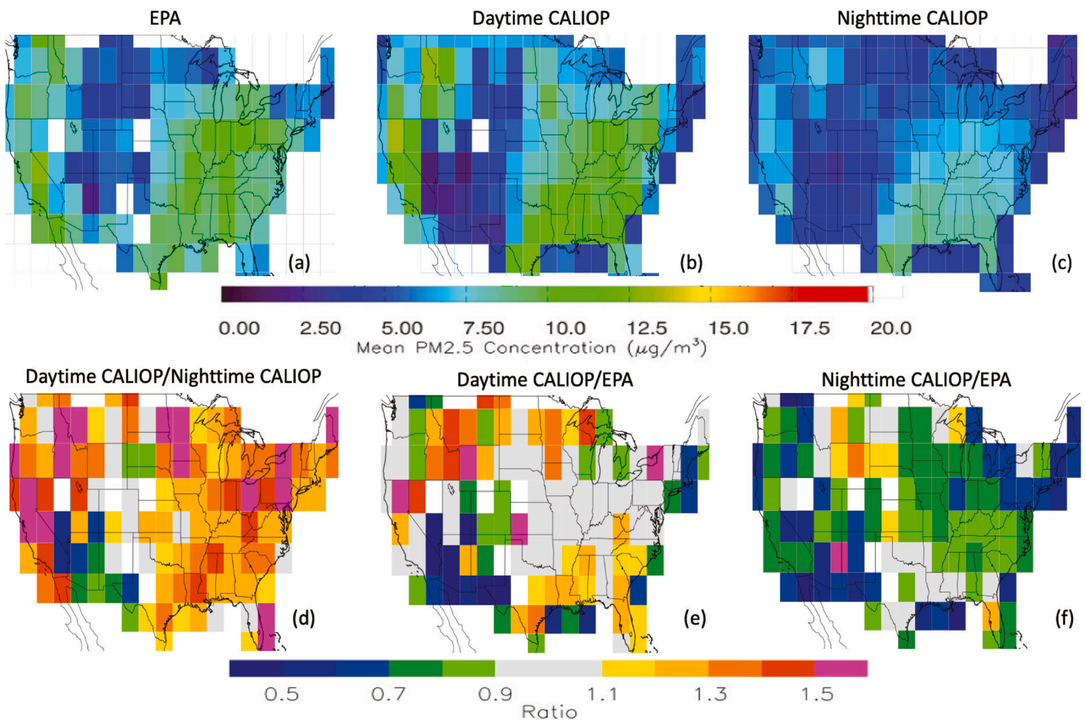
$$6 \quad C_{m2.5} = \frac{\beta \times \phi \times 1000}{(a_{scat} \times f_{rh} + a_{abs})}$$

$PM_{2.5}$ to PM_{10} ratio (ϕ)

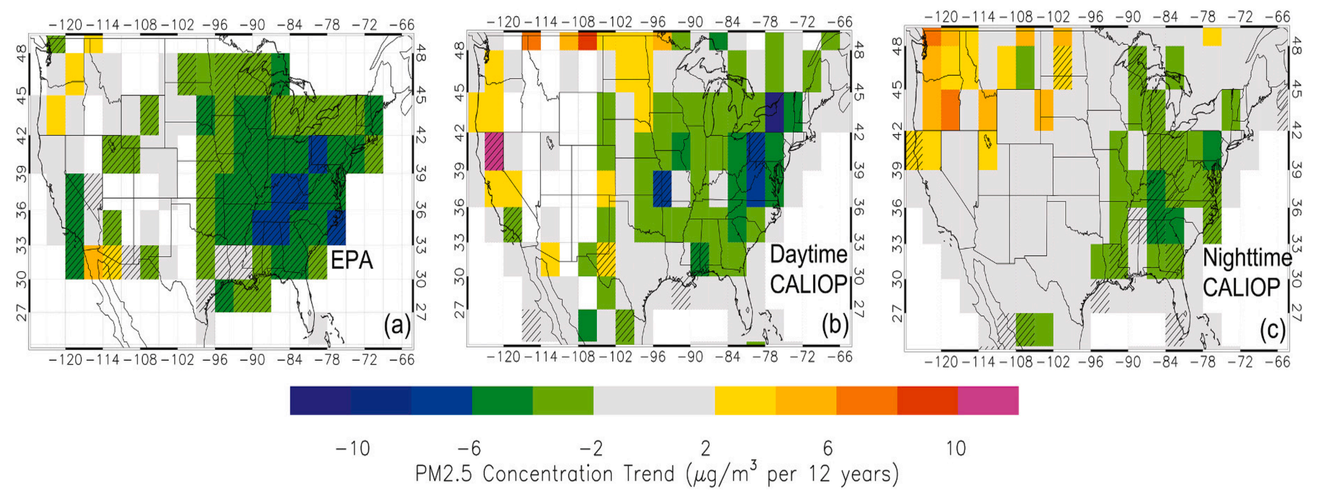
- Must be considered, as CALIOP-derived PM density is for all particle sizes
- Value of **0.6** is used (measured during SEAC⁴RS)

- $C_{m2.5}$ → $PM_{2.5}$ mass concentration (μg m^{-3})
- a_{scat} → mass scattering efficiency (m^2 g^{-1})
- a_{abs} → mass absorption efficiency (m^2 g^{-1})
- ϕ → $PM_{2.5}$ to PM_{10} ratio (**0.6**)
- β → extinction coefficient (m^{-1})
- a → mass extinction efficiency (m^2 g^{-1})
- C_m → PM mass concentration (g m^{-3})

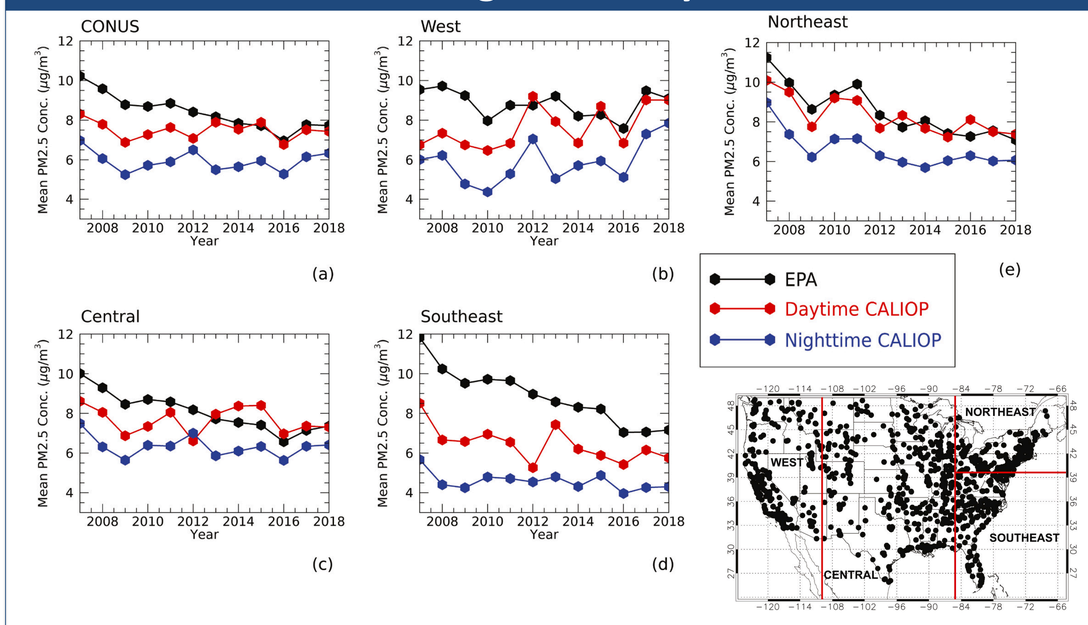
3. Spatial Mean $PM_{2.5}$ from EPA and CALIOP



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

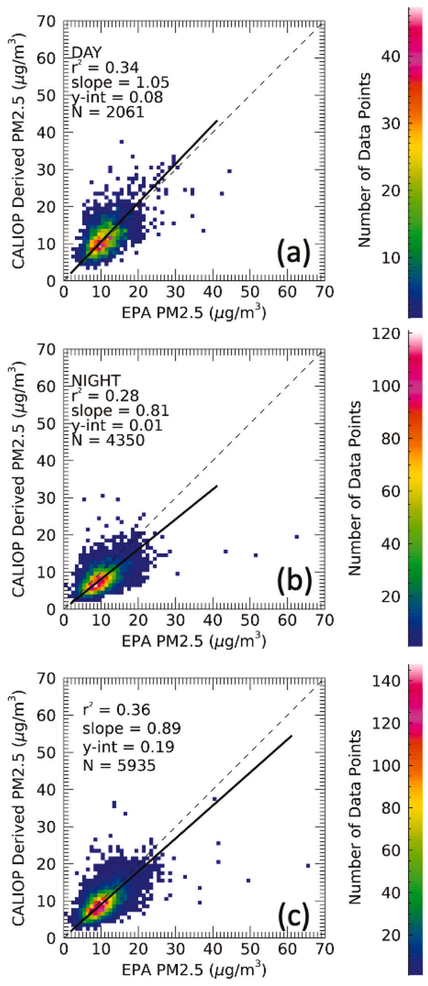


5. Regional Analysis



	$PM_{2.5}$ Concentration Trend (μg/m³ per 12 years)		
Region	*EPA*	*Daytime CALIOP*	*Nighttime CALIOP*
CONUS	-2.71	-0.39	-0.28
West	-0.77	2.12	1.66
Central	-3.01	-0.51	-0.58
Southeast	-4.58	-1.98	-0.79
Northeast	-3.9	-2.46	-2.25

6. Initial Validation Efforts



7. PMLS Working Group for MIRA

What is MIRA?

- A forum that fosters international collaborations amongst the aerosol Modeling, In situ, and Remote sensing specialties
- Purpose: to contextualize both observations and model results through encouragement of holistic projects and collaborations

Particulate Matter from Lidars in Space (PMLS) Working Group:

- Focuses on the development of robust $PM_{2.5}$ retrievals from global lidar measurements for use in air quality research and applications
- Some benefits of $PM_{2.5}$ retrievals from spaceborne lidars:
  - Curtains/profiles of $PM_{2.5}$ (i.e., vertical information)
  - Means of improving/validating models & important tool for $PM_{2.5}$ data assimilation
  - Improve/validate passive remote sensing techniques to derive $PM_{2.5}$
  - Nighttime characterization of air quality

Request for international datasets

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

8. Conclusions and Future Work

- Spatial distribution of twelve-year mean $PM_{2.5}$ concentrations derived from CALIOP compares reasonably well to that of $PM_{2.5}$ collected at U.S. EPA stations
- Encouraging relationship found between CALIOP-derived $PM_{2.5}$ and EPA-observed $PM_{2.5}$
- Decreasing $PM_{2.5}$ pattern over majority of eastern CONUS (i.e., air quality improvement), consistent with EPA-based $PM_{2.5}$
- Some areas of western CONUS show increasing pattern in CALIOP-derived and EPA-based $PM_{2.5}$ (i.e., air quality degradation)

Future efforts include:

- Spatial and temporal representativeness issues
- Impact of varying CALIOP aerosol types and corresponding mass extinction efficiencies
- Mixed layer/planetary boundary layer height (derived from lidar data or provided by models
- Application of $PM_{2.5}$ derivation method to other regions (i.e., global analysis)

9. Acknowledgements

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