National Aeronautics and Space Administration

FY23 Topic Areas Research and Technology Development (TRTD)

Cost-effective real-time sensing of speciated fine particulate matter air pollution

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Strategic Focus Area: Atmospheric composition and dynamics

Objectives

The objective of this research is to explore a novel approach for cost-effective, real-time monitoring of speciated ambient fine particulate matter (PM). We seek to reduce the reliance on filter weighing and post-sampling laboratory-based chemical composition assessments by investigating the feasibility of using real-time physical/optical measurements to estimate speciated PM concentrations from in-situ sensors. Determining the most effective speciated PM estimators will help conceptualize a sensor package that could be deployed as a real-time complement to filter-based samplers within air quality monitoring networks.

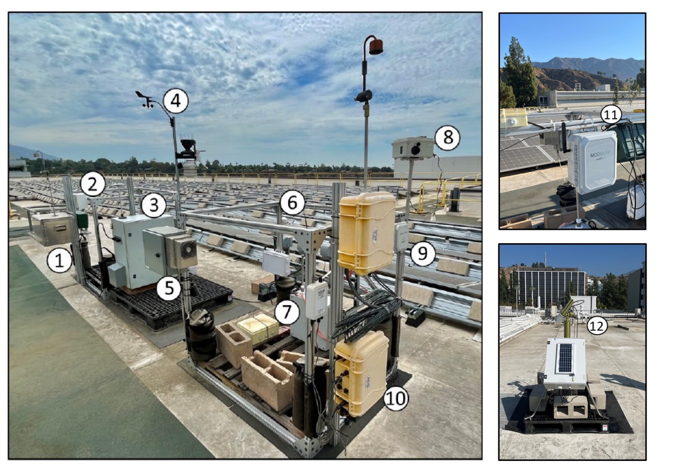
Background

Partitioning airborne PM into chemical constituents is essential for source attribution, development of targeted regulatory controls, and assessment of health effects. This research is aimed at revolutionizing how how mapping of speciated PM is done by confronting the expense, complexity, temporal resolution, and latency of current techniques employed by regulatory agencies. A rooftop air quality monitoring facility at JPL is integral to this research. Machine learning and multivariate linear regression modeling are key elements of the PM estimation methodology.

Approach and Results

Our principal goal in FY23 was to operate the JPL air quality facility used in this research (Fig. 1) and to explore the efficacy of real-time optical measurements in estimating total and speciated PM mass concentrations. An additional goal was to assess the air quality environment at JPL.

- The AirPhoton SS5 filter sampler collects PM2.5 on Teflon filters for subsequent chemical analysis (Fig. 2). Elevated PM2.5 levels in late 2021/early 2022, with a significant nitrate contribution, are likely due to increased emissions caused by supply chain disruptions that resulted in a major backlog of ships and a historic increase in operations at the ports of Los Angeles and Long Beach. Higher levels of sea salt in Spring/Summer are consistent with increased southwesterly winds. Elevated ammonium sulfate in Spring/Summer is due to increased photochemical activity from higher insolation.
- The total mass and sulfate components of the sampled PM2.5 were used to calibrate the coefficients of a multivariate linear regression model, in which column aerosol optical depth (AOD) at 440 nm from the CIMEL sunphotometer and meteorological data (temperature, relative humidity, and wind speed/direction) from the Davis weather station were used as predictors (Fig. 3).
- The MPP100 polar nephelometer measures polarized aerosol scattering at 3 visible wavelengths and 6 scattering angles between 26° and 154°. An empirical approach using raw sensor output of the nephelometer's green band at a scattering angle of 102.8° at both 0° and 90° to the scattering plane, along with temperature and relative humidity, was used to generate a linear regression model that predicts PM2.5 mass concentration. Co-located measurements from the GRIMM optical particle counter were used as truth. Results are shown in Fig. 4 for size cutoffs of 2.5 μm and 10 μm in the nephelometer. The PM peak early in the month is from July 4th fireworks. The larger size cut enabled detection of coarse particles associated with a dust event on July 31.
- The AethLabs MA350 multi-wavelength microaethalometer provides real-time insight into the composition of light absorbing carbonaceous particles. In FY22, we demonstrated the ability to distinguish black carbon from fossil fuel and biomass burning aerosols. In FY23, we compared MA350 data with ultrafine particle concentrations determined from the co-located scanning electrical mobility spectrometer (SEMS). BC data from August 2022 and SEMS data from September 2022 are plotted together in Fig. 5.



1	AirPhoton MPP100 nephelometer	8	CSU AMOD
2	Aeroqual AQY	9	QuantAQ Modulair-PM
3	Aerosol Dynamics, Inc. SEMS	10	AirPhoton SS5
4	Davis Vantage Pro2 weather station	11	QuantAQ Modulair
5	AethLabs microAeth MA350	12	CIMEL sunphotometer
6	PurpleAir PA-II	*	2B Technologies NO_x monitor
7	GRIMM EDM 164	*	Serinus 51 SO2 monitor

Figure 1. Rooftop equipment complement at JPL.

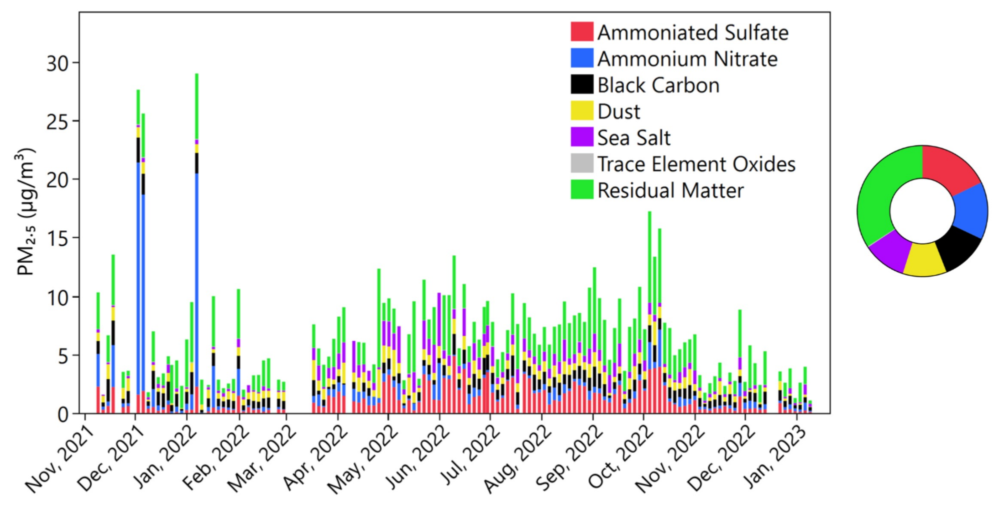


Figure 2. Chemical composition of ambient PM2.5 samples collected by the AirPhoton SS5 sampler.

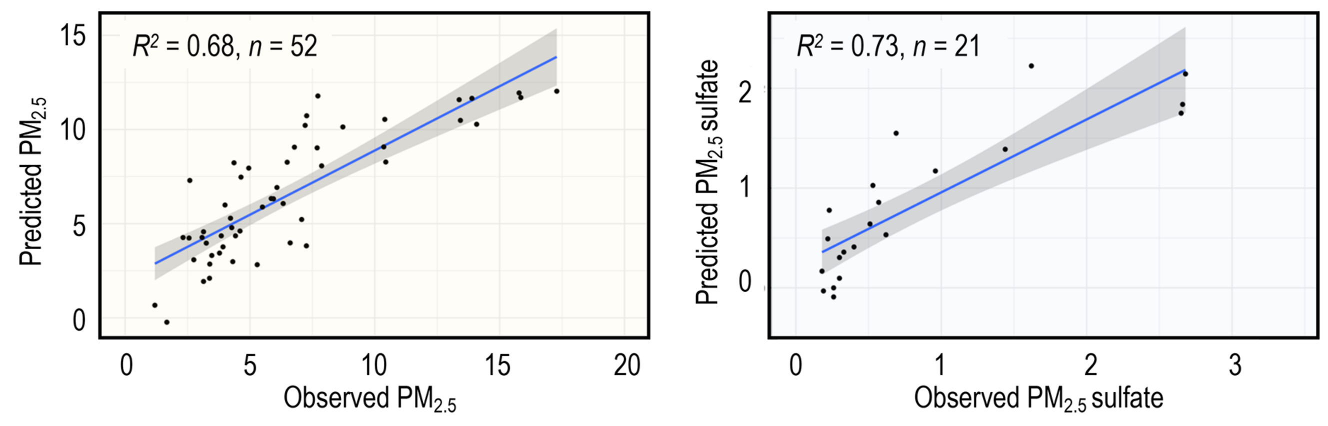


Figure 3. Results of fitting a multivariate linear model to observed total and sulfate PM2.5 mass concentrations.

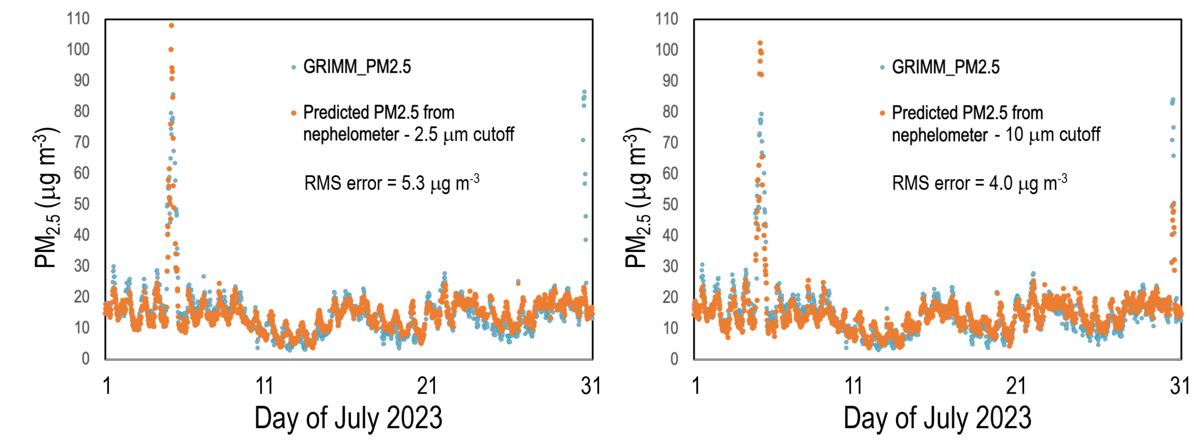


Figure 4. Time series of measured and predicted PM2.5 mass concentration for the month of July 2023, using two different size cuts on the nephelometer.

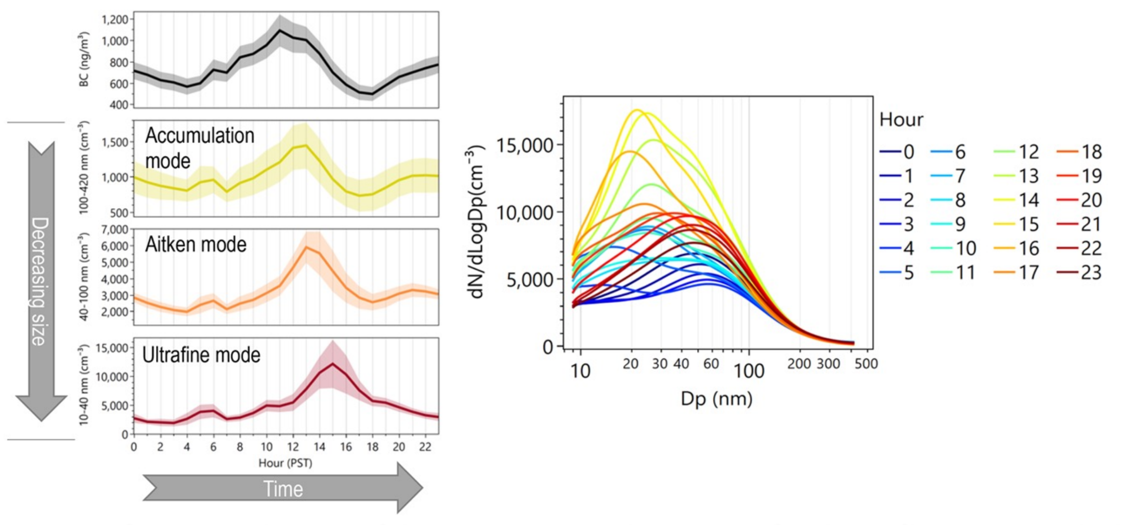


Figure 5. Results from the SEMS show the frequent formation of large numbers of ultrafine particles (UFPs), particularly during the afternoon, most likely from the condensation of low-volatility vapors. Such UFP events have not been extensively studied in the Los Angeles area before. Black carbon (BC) concentrations also show midday peaks, which correlate with increased truck traffic on nearby freeways.

Significance/Benefits to JPL and NASA

While airborne PM has been associated with myriad adverse health outcomes, the relative toxicity of different PM types is poorly understood. Missions such as JPL's Multi-Angle Imager for Aerosols (MAIA) will improve this understanding. This research aims to enable breakthroughs in how satellite remote sensors obtain the data needed to transform aerosol physical and optical characteristics into near-surface PM composition.

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