National Aeronautics and Space Administration

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

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Strategic Focus Area: Atmospheric composition and dynamics

Objectives

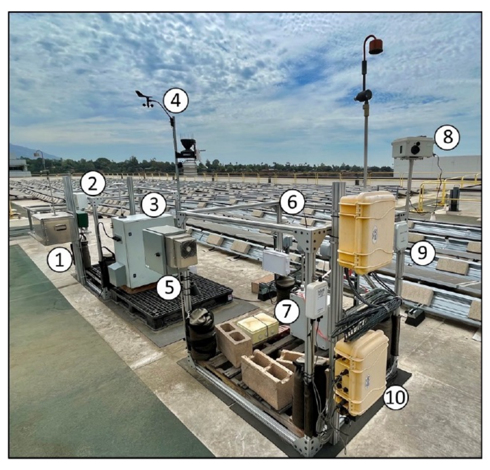
The objective of this research is to explore a novel approach for cost-effective, real-time monitoring of speciated ambient fine particulate matter (PM). We seek to reduce the reliance on filter weighing and post-sampling laboratory-based chemical composition assessments by investigating the feasibility 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 mapping of speciated PM is done by confronting the expense, complexity, temporal resolution, and latency of current techniques employed by regulatory agencies. An air quality monitoring facility on the roof of JPL building 301 is integral to this research. Machine learning (ML) is a key element of the PM estimation methodology.

Approach and Results

- Our approach is to use state-of-the-art optical scattering, absorption, and particle size measurements, gas-phase data, and meteorological information as real-time compositional PM predictors and to train machine learning (ML) algorithms to transform these measurements into speciated PM speciation concentrations.
- Our principal goals in FY22 were to complete the installation and begin operation of the JPL air quality facility used in this research (Fig. 1).
- Co-located filter-based PM data are used as “truth”. An AirPhoton SS5 and a Colorado State University Aerosol Mass and Optical Depth (AMOD) sampler collect PM on filters for subsequent chemical analysis (Fig. 2).
- An AethLabs MA350 multi-wavelength aethalometer provides real-time data on the composition of light absorbing carbonaceous particles. We demonstrated the ability to distinguish black carbon from fossil fuel and biomass burning aerosols (Fig. 3).
- We installed a custom polarization-sensitive polar nephelometer that measures aerosol scattering at multiple wavelengths and scattering angles (Fig. 4).
- The GRIMM EDM 164 monitor is a near-reference-grade total PM and particle size sensor. The PurpleAir-II is a low-cost instrument calibrated by co-location with the GRIMM. We showed that calibrated PA-II PM2.5 data perform well over a large range of particle concentrations.
- To detect ultrafine particles, we procured a scanning electrical mobility spectrometer (SEMS) from Aerosol Dynamics, Inc. A weatherproof enclosure was purchased and in mid-FY22 the SEMS began operating on the roof of B301 (Fig 5).
- California Air Resources Board loaned reference-grade SO2 and NO2 monitors to this project. Due to complexities associated with deployment on the roof of B301, the instruments were installed in B306. Research grade NO2/SO2 AQMesh sensors demonstrated that the measurements from B306 and B301 are highly correlated.
- To provide meteorological input to the ML model, a Davis weather station provides temperature, RH, and wind speed/direction data in real time.
- Machine learning is being used to test, identify, and rank the most capable speciated PM2.5 predictors. The ML code is currently being tested using data collected from the instruments described above.



1	AirPhoton MPP 100 nephelometer
2	Aeroqual AQY
3	Aerosol Dynamics, Inc. SEMS
4	Davis Vantage Pro2 weather station
5	AethLabs microAeth MA350
6	PurpleAir PA-II
7	GRIMM EDM 164
8	CSU AMOD
9	QuantAQ Modulair-PM
10	AirPhoton SS5

Figure 1. Equipment complement on JPL B301.

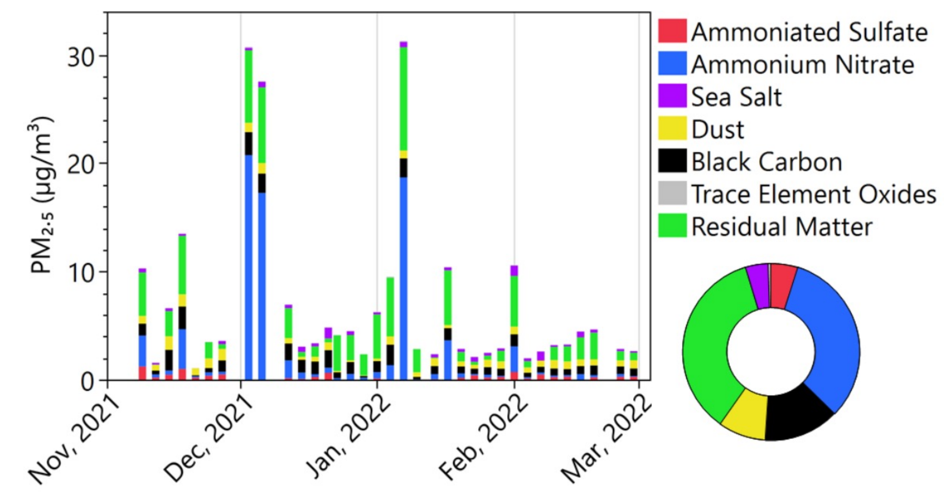


Figure 2. Chemical composition of ambient PM2.5 samples collected by the AirPhoton SS5 sampler.

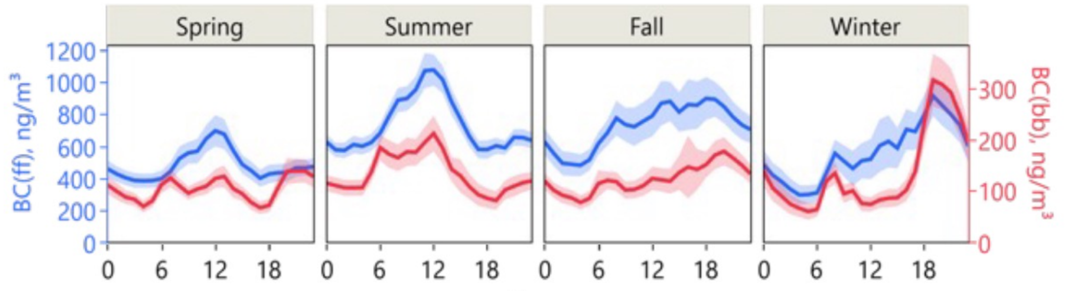


Figure 3. Fossil fuel (ff) and biomass burning (bb) black carbon (BC). Mid-day ff BC peaks coincide with higher truck traffic in nearby freeways. Night-time bb BC peaks in winter suggest enhanced wood burning in nearby residential areas.

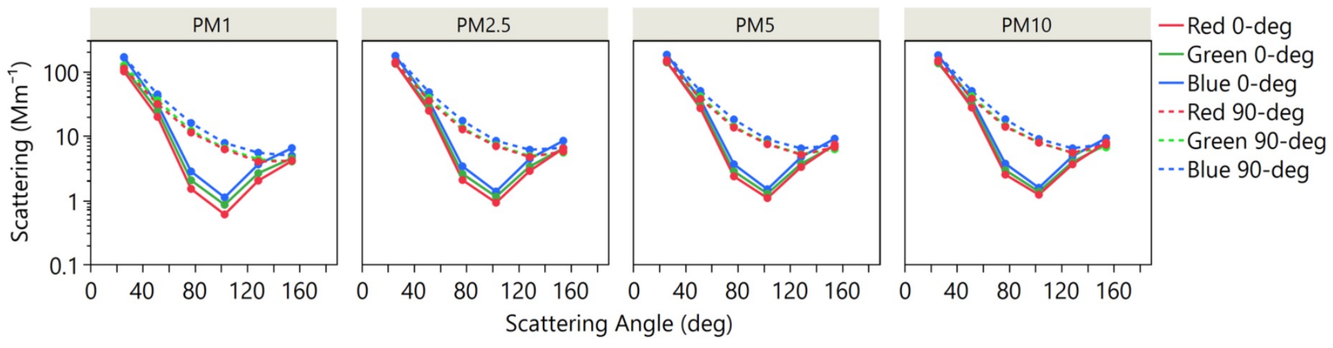


Figure 4. Scattering coefficients at 440, 532, and 632 nm and 6 scattering angles of the nephelometer suggest particle sizes on the order of or smaller than the illuminating wavelengths..

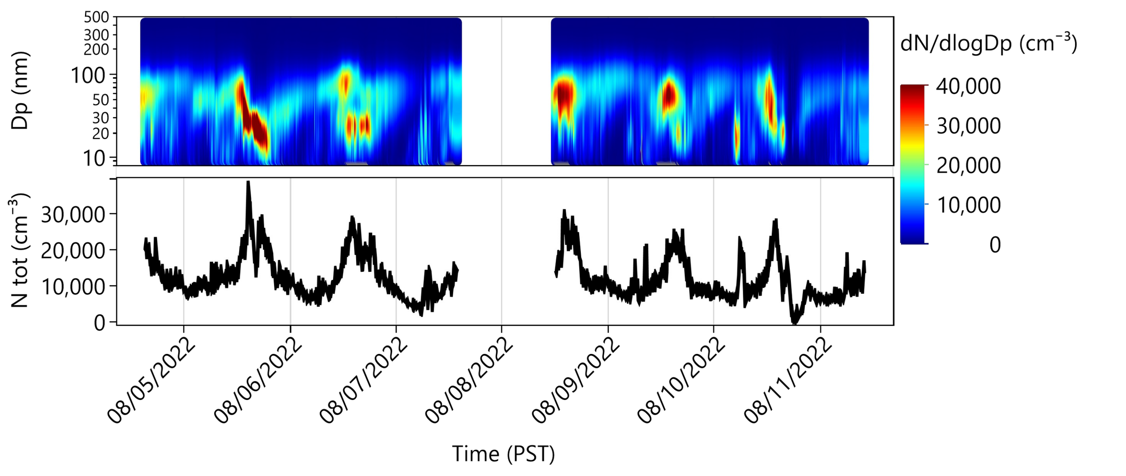


Figure 5. A week-long SEMS measurement shows strong temporal variation in size distribution and total number concentrations of ambient ultrafine particles in Pasadena. Enhanced concentrations in the afternoon likely indicate secondary particle formations.

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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