Addition of Particulate Matter Sensors at CASTNET Sites

Kevin Mishoe[1], Christopher Rogers[2], Jayde Alderman[1], Anna Hyland[1], Michael Smith[1]

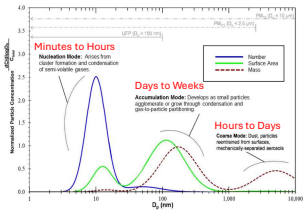
[1]WSP USA Environment & Infrastructure Inc., Gainesville, FL [2]WSP USA Environment & Infrastructure Inc., Jacksonville, FL

Introduction

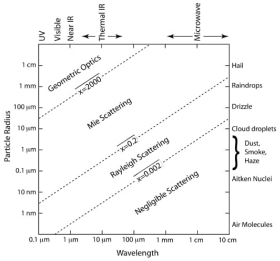
As a part of EPA's 3-year modernization plan for CASTNET, sensor-based PM measurements were added to all EPA-and IRL council-sponsored CASTNET monitoring sites. As of June 2026, 68 PurpleAir Flex sensors and 63 QuantAQ Modulair sensors are reporting data. In addition, 21 of the QuantAQ units include electrochemical sensors for ozone, NO, NO_2, and CO. While CASTNET measures the major components of $PM_{2.5}$ (SO_4^{2-}, NO_3^-, NH_4^+), the network has not previously reported $PM_{2.5}$ mass concentrations. Data provided by low-cost sensors are not used for regulatory purposes such as determining attainment of the National Ambient Air Quality Standards (NAAQS), the concentrations reported are being compared to the recently revised $PM_{2.5}$ NAAQS, which was lowered to 9 µg/m³ in February 2024. The PurpleAir data are also included in the AIRNow Fire & Smoke Map for near real-time reporting to the public. Hourly lower-cost sensor data are posted daily on the EPA CASTNET website, and all historical CASTNET filter pack data (PM precursors) through 2025 have been posted in EPA's Air Quality System (AQS).

Does My Mass Look Big in This Light?

The Federal Reference Method (FRM) and Equivalent Method (FEM) for PM concentration is a direct mass measurement. Sensor-based methods, while significantly less expensive, rely on an indirect measurement of mass. Specifically for the PurpleAir and Modulair sensors, the scattering of light by small particles. The type of scattering, and hence the direction of the scatter, depends on the size of the particle and wavelength of light. For the PM sizes of concern, near-IR wavelengths scatter in the Mie regime (particles with diameters approximately equal to the wavelength of the incident ray). Due to the extremely large number of ultrafine particles (<1µm), individual particle scattering cannot be counted and an integrated response is reported by the nephelometer. The Modulair uses an Optical Particle Counter (OPC) to count and bin individual particles for sizes larger than 1 µm. In theory, this should make PM_{10} measurements more accurate, under a wider array of circumstances, than the PurpleAir nephelometer alone.

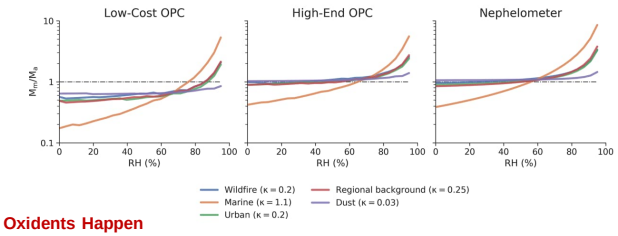


Number, Surface Area, and Mass Distribution



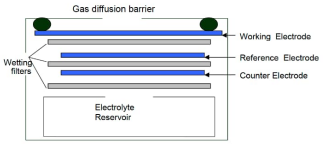
Optical Scattering by particle size and wavelength

In addition, the refractive index, particle density, and hygroscopic growth factor all vary with the chemical composition of the PM and must be approximated from particle size.

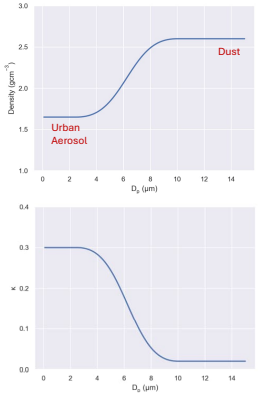


Oxidents Happen

Twenty-one of the Modulair PM sensors include electrochemical sensors for ozone, NO, NO_2, and CO. These sensors work by allowing the species of interest to react with a working electrode, producing an induced current proportional to the species concentration. Electrochemical cells are highly sensitive to changing ambient conditions like temperature and relative humidity. Significant corrections are applied and overall accuracy is highly dependent on calibration. In addition, the oxidizing electrode responds to ozone and NO_2 equally. As a result, one sensor measures ozone and NO_2 and a second filtered sensor measures only NO_2. The ozone concentration is determined by difference.

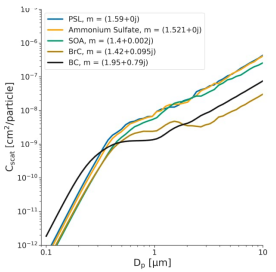


In real particulate compositions, particle density and hygroscopicity are complex and depend on specific chemical compositions. Approximations are used for particle density and hygroscopic growth using particle diameter as a surrogate for composition. For example, fine urban aerosols are typically less dense than large mineral dust particles. Likewise, the hygroscopic growth of small particles is typically more rapid than larger particles, however a significantly different composition such as a heavily marine originated aerosol will have a much larger hygroscopic growth than is accounted in these approximations.



Hygroscopic Growth Factor κ	
$(NH_4)_2SO_4$	0.53
NH_4NO_3	0.67
NaCl	1.28
H_2SO_4	0.9
$NaNO_3$	0.88
$NaHSO_4$	0.91
Na_2SO_4	0.8

Hygroscopic growth factors for selected PM components

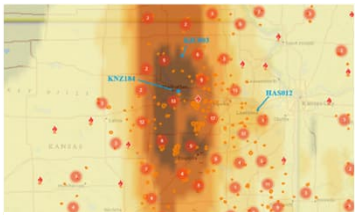


Scattering intensity by particle size for selected refractive indexes

Wildfire/Biomass Burning

The CASTNET PM sensors are being used to investigate biomass smoke plumes affecting local areas. Using NOAA's Hazard Mapping System, smoke frequency and intensity affecting sites can be referenced with total PM mass, PM precursor and speciation information from CASTNET's filter pack (SO_4^{2-}, NO_3^-, NH_4^+), in addition to impacts on ozone and ozone precursors. The chemical composition of smoke is challenging for optical methods to accurately measure. Black carbon is more absorptive than typical particulate constituents, the average particle density is lower than the particle density assumed to calibrate the sensors, and the Plantower nephelometer has a non-linear response at very high concentrations (>300µg/m³).

Smoke Events Across NTN network 7/25/2021



PM Forecast from BlueSky Canada 4/8/2026
firesmoke.ca

	PM 1.0	PM 2.5	PM 10	Ozone	NO	NO2	CO
PurpleAir	Dual Plantower PMS-6003			-	-	-	-
Modulair	Plantower PMS-5003	Alphasense OPC-N3		Alphasense OX-B431	Alphasense NO-B4	Alphasense NO2-B43F	Alphasense CO-B4

Sensor Comparison

Comparisons of the two types of PM sensors are shown for three sites. In general, the $PM_{2.5}$ measurements agree the closest, which is due to the EPA correction applied to the PurpleAir concentrations. The largest differences are seen in the PM_{10} measurements, which is likely attributable to the direct measurement in the Modulair using the OPC versus the modeled particle size distribution used by the PurpleAir sensors. The geometry of the nephelometer restricts the aspiration efficiency of particles larger than 2.5 µm.