Each SPARTAN (Surface PARTiculate mAter Network) site contains two instruments:
1. Three-wavelength integrating nephelometer
2. Automated filter-based sampler

We collocate with existing sun photometers

Collocating with sun photometers allows for empirical estimates of the relationship of PM$_{2.5}$/AOD to evaluate model calculations. PM$_{2.5}$ is inferred from filters that sample over a 9-day period modulated by nephelometer aerosol scattering. This sampling procedure cost-effectively allows measure of long-term, 24-hour, and hourly PM$_{2.5}$.

![SPARTAN Instrument](image)

**Figure 2:** Left: Temporal variation in PM$_{2.5}$ Right: 24-hour PM$_{2.5}$ comparison.

Hourly PM$_{2.5}$ inferred from aerosol scatter compares well to hourly BAM measurements in Beijing, China. A Air Photon nephelometer scatter also compares well to the Optec NGN-2 used by IMPROVE in Mammoth Cave National Park, USA.

![Nephelometer Comparison](image)

**Figure 3:** Map: GEOS-Chem annual mean $\eta$ (ratio of surface PM$_{2.5}$ to total-column AOD) at satellite overpass times (1000 to 1200 and 1300 to 1500 hours local time) at RH < 80%. White space indicates water. Values from in situ observations are overlaid at colored circles on larger circles showing modeled values sampled coincidently. Pie Charts show PM$_{2.5}$ chemical speciation results from SPARTAN compared with GEOS-Chem modeled values sampled coincidently.

Initial results show that measured PM$_{2.5}$/AOD ratios tend to be highest in regions that experience high levels of PM$_{2.5}$ and have local PM sources (e.g., Beijing and Kampur). This trend appears to hold in GEOS-Chem, however GEOS-Chem also suggests that regions experiencing biomass burning events and elevated dust concentrations also have high PM$_{2.5}$/AOD ratios.

**Chemical Speciation**

Sampled filters are analyzed at Dalhousie University for mass (clean room, RH 30-40%), equivalent black carbon (Smoke Stain Reflectometer), water-soluble ions (Ion Chromatography), and major trace metals (Inductively-coupled plasma – Mass Spectrometry).

Dust/soil = Al, Fe, Ti
Sea salt (SS) = Na, Cl = 41% water
Sulfate = measured by IC = 27% water
Nitrate = measured by IC = 27% water
Black carbon = Equivalent-BC (measured by reflectance)
Trace Element Oxides (TEO) = P, V, Cr, Mn, Ni, Cu, Zn, As, Se, Pb
Residue = PM$_{2.5}$ = (Soil + SO$_4^-$ + NO$_3^-$ + NH$_4^+$ + SS + E-BC)

**Figure 4:** Annual mean scale height (ratio of total-column AOD to total ground scatter) at satellite overpass times (1000 to 1200 and 1300 to 1500 hours local time) at RH < 80%. White space indicates water. Values from in situ observations are overlaid at colored circles on larger circles showing modeled values sampled coincidently.

**OBSERVATIONS**

- Mean PM$_{2.5}$ varies by an order of magnitude while $\eta$ varies by over a factor of 4 across SPARTAN sites (32 – 139).
- Measurements indicate that variation in $\eta$ is driven by variation in scale height (related to vertical profile of aerosol scattering) and, to a lesser extent, mass scattering efficiency whereas diurnal variation is minimal.
- No clear global bias in measured vs. modeled PM$_{2.5}$ concentrations generally being lower than GEOS-Chem values at SPARTAN sites. Regional biases in South Asia.
- GEOS-Chem PM$_{2.5}$ speciation values are broadly consistent with SPARTAN results.
- Residual mass measured by SPARTAN is consistent with OM reported by GEOS-Chem. Sulfate and dust are the dominant inorganic species in SPARTAN measurements and GEOS-Chem.

**STRATEGY:** Compare Empirical and Modeled $\eta$ values

A key source of uncertainty in satellite-based estimates of PM$_{2.5}$ is the relationship between surface PM$_{2.5}$ and AOD:

$$\eta = \frac{\text{PM}_{2.5}}{\text{AOD}_{10-14}}$$

Empirical $\eta$ values are obtained by SPARTAN and collocated sun photometers. SPARTAN provides an ongoing, global assessment of $\eta$ and is compared with GEOS-Chem. The ratio, $\eta$, is further broken down into three components for interpretation:

- Inverse Scale Height (km$^{-1}$)
- Diurnal Variation (unitless)
- Inverse mass scattering efficiency ($\mu$m$^{-1}$)

For most sites, scale height contributes to > 50% of the spatial variation in $\eta$. Mass scattering efficiency also plays an important role.

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