# The relevance of column integrated measurements in the Baltimore-Washington area during Discover-AQ

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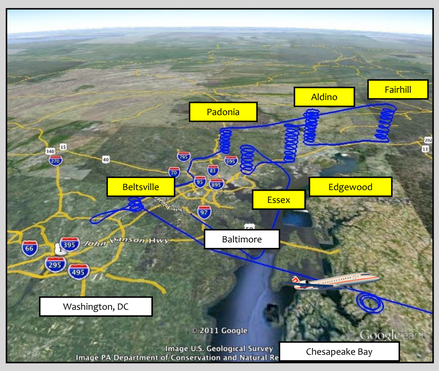
## Introduction & Objectives




A challenge for satellites measuring air quality is to distinguish between pollution high in the atmosphere and that near the surface where people live and breathe. In summer 2011 NASA began a multi-year airborne field campaign called **D**eriving **I**nformation on **S**urface conditions from **C**olumn and **V**ertically **R**esolved **O**bservations **R**elevant to **A**ir **Q**uality (DISCOVER-AQ) to tackle this challenge. The objectives of DISCOVER-AQ included:

- Determine the contribution of low level pollution to the AOD
- Examine the AOD contribution of the loadings versus the relative humidity
- Comparison of the ground based and integrated column measurements

## Measurements on the NASA P-3B

- Instruments calibrated before/during/after the campaign
- Data interpolation to the same frequency (1s Merge Files)
- Estimation of the optical properties (AOD, AE, SSA) from the TSI neph 3563

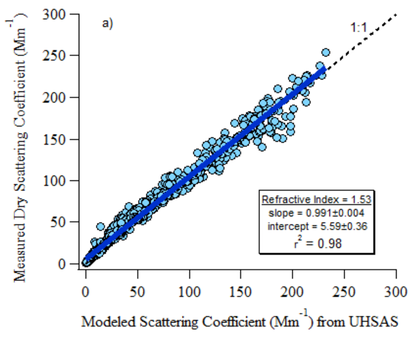
| Measured Parameter | Instrument | Size (μm) | Freq (s) |
|---|---|---|---|
| Dry Aerosol Size Distributions Aerosol Volume | TSI - SMPS | 0.01 - 0.3 | 60 |
| | DMT - UHSAS | 0.06 - 1 | 1 |
| | TSI -LAS | 0.09 -- 5 | 1 |
| Dry Total Scattering Coefficient | TSI-3563 | < 5 | 1 |
| f(RH) for Scattering | TSI-3563 (RH~ 80%) | < 5 | 1 |
| Total Absorption Coefficient | PSAP | < 5 | 1 |
| Aerosol WSOC concentration | PILS w/Sievers TOC | < 5 | 10 |
| Aerosol inorganic ion concentration | PILS / offline IC | < 5 | 240 |
| BC mass concentration | SP2 | 0.1 - 0.5 | 1 |

**SMPS** – Scanning Mobility Particle Sizer
**UHSAS** – Ultra-High Sensitivity Aerosol Spectrometer
**LAS** – Laser Aerosol Spectrometer
**PSAP** – Particle Soot Absorption Photometer
**PILS** – Particle Into Liquid Sampler
**TOC** – Total Organic Carbon
**IC** – Ion Chromatography
**SP2** – Single Particle Soot Photometer
**WSOC** – Water Soluble Organic Carbon

# RESULTS

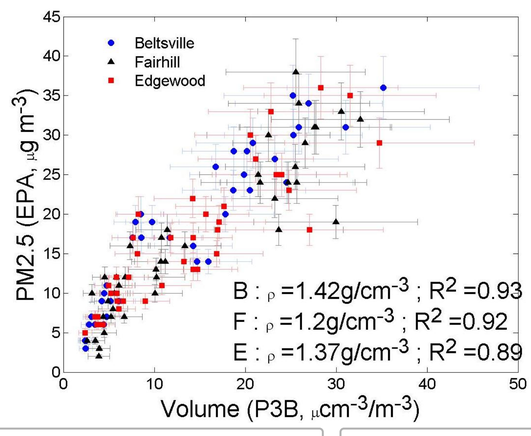
## Comparison aircraft (P3B) with PM2.5 measurements

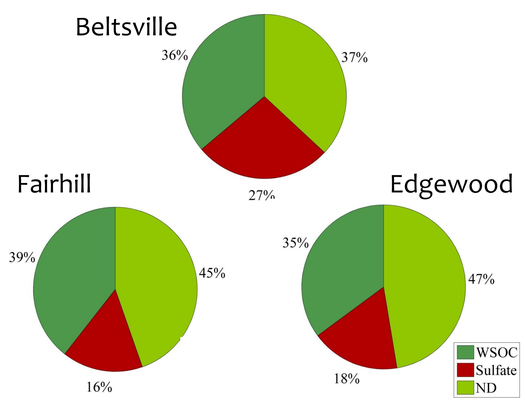
### Size distributions and PM2.5




UHSAS data were corrected according to the refractive index of ammonium sulfate ($V_{(NH4)2SO4}$ > 1.3 $V_{PSL}$) which was validated with the dry scattering coefficient

- EPA = BAM measurements
- Volume (dry) measured with the SMPS, UHSAS, APS at the lowest altitude (300-500m).



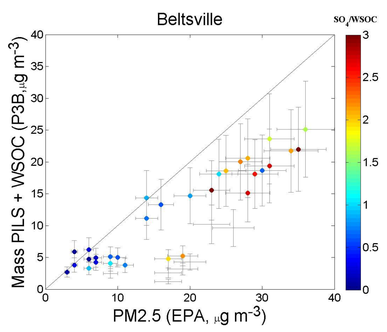



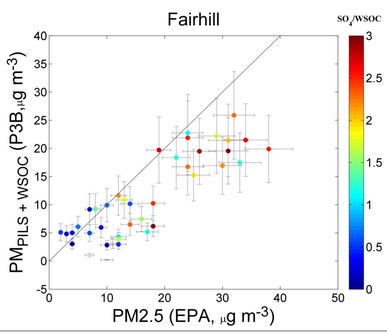

Density ~ **1.2 g cm³** gives good PM2.5 comparison

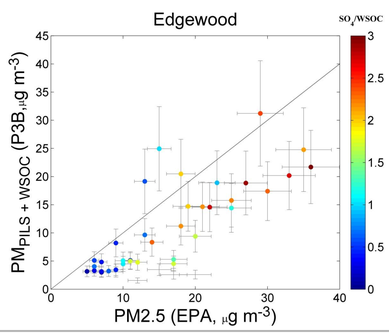
| | Density (g cm⁻³) | Region | Reference |
|---|---|---|---|
| $(NH_4)_2SO_4$ | 1.769 | -- | Handbook of Chemistry |
| OM | 1.18 (1.18) | W-LA (LA) | Turpin & Lim (2001) |
| OM | 1.18 | Pasadena | Turpin & Lim (2001) |
| OM | 1.22 | Rubidoux | Turpin & Lim (2001) |

### Mass measurements

$PM2.5_{PILS + WSOC}$ : is underestimated because the insoluble species mass is missing.
The $SO_4$/WSOC ratio shows an increase of the sulfate with the mass.



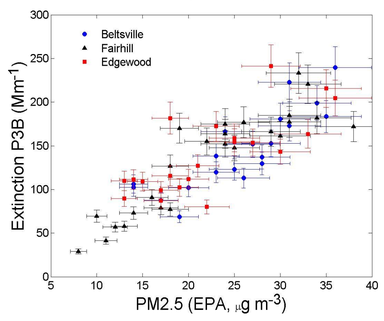




### Mass Extinction Efficiency (MEE)

| Sites | $R_{dry}$ | $MEE_{dry}$ |
|---|---|---|
| Beltsville | 0.84 | 5.9 |
| Fairhill | 0.90 | 6.2 |
| Edgewood | 0.75 | 4.8 |

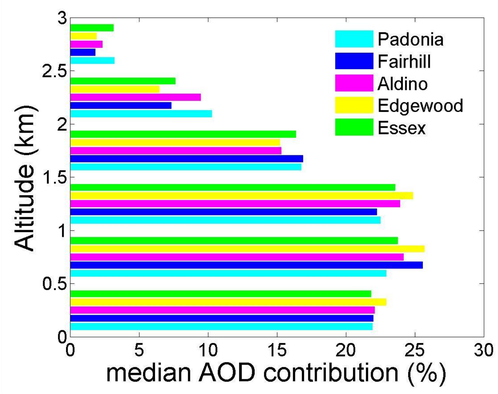
Values are consistent with the MEE found in the literature for Sulfate-OC-urban particles

Lower values at Edgewood maybe due to the sea salt entrained by the bay breeze




| | Aerosol type | MEE (m² g⁻¹) | Reference |
|---|---|---|---|
| Aircraft | Dust | 1.09 | Chen et al. 2011 |
| In situ | Dust | 1.23<br>0.93 | Jeong et al., 2008 |
| Lab | 38% $H_2SO_4$ | 2.7 | Carlon et al. 1977 |
| MODEL (AERONET /OMI) | OC | 7-8 | Kinne et al. 2003 |
| | BC | 10-11 | |
| | SU | 7-13 | |
| | SS | 0.9-1.3 | |
| | Dust | 0.9-1.1 | |
| Ground base | EC | 1.7-9.3 | Dillner et al. 2001 |

## Aerosol Optical Depth vs. PM2.5

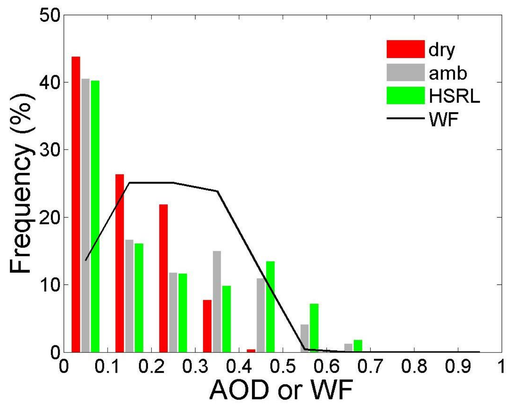



**Aerosol contribution :**

- 0-500m : interpolated from the lowest flight level
- 0-1500m : AOD contribution > 60 %
- >2000m : AOD contribution is lower than 10%.
- BL contribution 57-64%

**RH contribution :**

HSRL and ambient AOD are similar ➔ Validation of the measurements & low contribution of the aerosol layers in between 4000-8000m



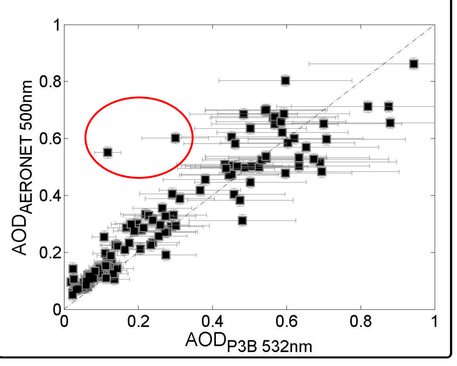

AOD ≤ 0.3 ➔ driven by the aerosol loadings
AOD > 0.4 ➔ driven by the RH

| AOD vs PM2.5 | References |
|---|---|
| AOD = 0.011 · PM2.5 – 0.062 | This work : Beltsville |
| AOD = 0.012 · PM2.5 – 0.0081 | This work : Fairhill |
| AOD = 0.018 · PM2.5 – 0.079 | This work : Edgewood |
| AOD = 0.019 · PM2.5 + 0.0022 | Shinozuka et al. 2007 : INTEXB |

**AERONET :**

- 247 spirals over the 6 sites
- 159 spirals coincident (~ 1h window)

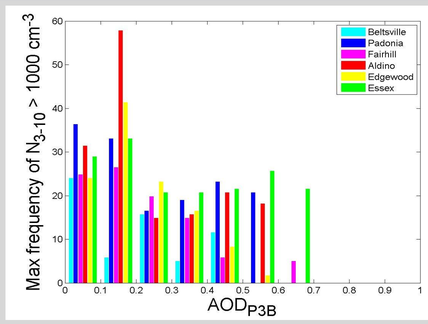
Good comparison except for 2 points : Biomass burning event & bay breeze day




## Health Issues :

High AOD are not necessarily related to highest values of the $N_{3-10}$ :
AOD < 0.2 ➔ frequency > 25 %

AOD is **NOT** a good criteria for air quality related to health




## Conclusions

- PM2.5 measured at the ground and derived from the dry size distribution are comparable
- The aerosol density is believed to be close to 1.2 gcm³ during the whole campaign
- MEE is calculated in between 4.8-6.2 $m^2g^{-1}$ corresponding to the values reported in the literature for urban aerosol / sulfate
- The lower layers (< 1.5 km) contribute to more than 60% of the total AOD
- The highest AOD values (> 0.4) are driven by the relative humidity
- The calculation of the AOD from the PM2.5 seems to be comparable with the one found in the literature

**References** :
1. Carlon et al., , Infrared extinction spectra of some common liquid aerosols, Appl. Opt., 16, 1598-1605, 1977.
2. Chen et al. Observations of Saharan dust microphysical and optical properties from the Eastern Atlantic during NAMMA airborne field campaign, Atmos. Chem. Phys., 11, 723-740, doi:10.5194/acp-11-723-2011, 2011. Jeong et al., 2008
3. Dillner et al., Measuring the Mass Extinction Efficiency of Elemental Carbon in Rural Aerosol, Aerosol Science and Technology , Volume 35, Issue 6, 2001
4. Kinne et al., Monthly averages of aerosol properties: A global comparison among models, satellite data, and AERONET ground data, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 108, NO. D20, 4634, doi:10.1029/2001JD001253, 2003
5. Shinozuka et al., Aircraft profiles of aerosol microphysics and optical properties over North America: Aerosol optical depth and its association with PM2.5 and water uptake, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, D12S20, 2007
6. Turpin & Lim, Species Contributions to PM2.5 Mass Concentrations: Revisiting Common Assumptions for Estimating Organic Mass, Aerosol Science and Technology , 35, pp 602–610, 2001.

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