Aerosol Optical Measurements from Detling, UK during ClearfLo

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Outline – Detling (ClearfLo)

- **Detling (Kent Showgrounds)**
  - London: ~33 miles WNW
  - Maidstone: ~3 miles SW
  - Power Station: ~8 miles North
  - Highways: ~0.15 mi S; A249 (1.5 mi S; M20)
  - Continental EUR: 50+ miles E/SE

- **On-line Instrumentation**
  - Aerosol: PASS-3, PASS-UV, SP2, CAPS, SMPS, LAS
  - Gas-phase: CO₂, H₂O, CH₄

- **Off-line Filter Samples**
  - 2-6 hour Ambient and Denuded: SEM/XRD
  - 24/48 hour: C-13 (Total Carbon and WSOC)

http://www.clearflo.ac.uk/
Experimental Set-up

- **Detling ST1**
  - Aerosol line: behind the ARI Thermal Denuder
    - PASS-3: scattering and absorption (781, 532, 405 nm)
    - SP2: black carbon (BC) number, mass, size distribution
    - SMPS: size distribution
  - Gas-phase line: CO$_2$, H$_2$O, CH$_4$

- **Detling PC1**
  - Line 1 – PASS-3, LAS, TD, SEM/XRD filters
  - Line 2 – 10 LPM quartz filters for isotopic analysis

- **North Kensington**
  - Manchester Aerosol TD line: PASS-UV
    - Scattering and absorption at 375 nm
    - Duplicate of Detling aerosol measurements
      - Same TD temperatures, same TD, similar flow through the TD
Time Series

EUR? Outflow

London Outflow

Kingsnorth Power Station

![Time Series Chart](chart.png)
Extinction = Absorption + Scattering?
CAPS and PASS3

- CAPS Extinction at 445 nm (TD line)
- PASS-3 Absorption + Scattering at 405 nm corrected to 445 nm
  - 2nd half of the campaign intercomparison
  - EAE from PASS data = 1.8 ($R^2 = 0.8$)
  - Good first comparison of CAPS and PASS
  - Need to determine EAE from CAPS data
BC Increases with Incomplete Combustion (CO/CO₂)
Absorption Enhancement? Ambient vs 250°C TD

- Need to be corrected for TD losses (Huffman et al.)
- Will be compared with SP2, SP-AMS
- Scattering enhanced by ~2-10x
Conclusions

- Rich dataset on BC measurements with thermal denuder
  - Optical Properties: SP2, CAPS, PASS
  - Size: SMPS and LAS
  - Chemical: AMS, SP-AMS, CIMS

- Extinction from CAPS = PASS Absorption + Scattering

- BC increases with Inefficient Combustion (CO/CO₂)

- Evaluating absorption enhancements of BC coatings
  (TD losses, background corrections, uncertainties)

- Working with ClearfLo team on integrating chemical
  measurements (ARI), SEM imaging (Mazzoleni), testing
  mixing state models (Cappa), comparing data with North
  Kensington site (Allan)
Acknowledgements

- DOE ASR
- LANL Director’s Postdoctoral Fellowship
- ClearfLo
- Kent Showground
Ambient PASS3 EAE’s

- $EAE_{781/405} = 1.85$ ($R^2 = 0.84$)
- $EAE_{532/405} = 1.15$ ($R^2 = 0.95$)
- $EAE_{781/532} = 2.30$ ($R^2 = 0.87$)
- Average = 1.77

$$\beta_{\lambda_0} = \left(\frac{\lambda}{\lambda_0}\right)^{-AE}$$
Operated by Los Alamos National Security, LLC for NNSA

**TD (all Temperatures) PASS3 EAE’s**

- $EAE_{781/405} = 1.10 \ (R^2 = 0.81)$
- $EAE_{532/405} = 0.82 \ (R^2 = 0.91)$
- $EAE_{781/532} = 1.86 \ (R^2 = 0.87)$
- **Average** = 1.3

\[
\beta_{\lambda} = \left( \frac{\lambda}{\lambda_0} \right)^{-AE} \\
\beta_{\lambda_0} = \left( \frac{\lambda}{\lambda_0} \right)^{-AE}
\]
**Ambient PASS3 SAE’s**

- $\text{SAE}_{781/405} = 1.89 \ (R^2 = 0.89)$
- $\text{SAE}_{532/405} = 1.21 \ (R^2 = 0.96)$
- $\text{SAE}_{781/532} = 2.37 \ (R^2 = 0.89)$
- **Average** = 1.82

\[
\beta_{\lambda} = \left(\frac{\lambda}{\lambda_0}\right)^{-AE}
\]
Ambient PASS3 AAE’s

- $\text{AAE}_{781/405} = 1.10$ ($R^2 = 0.55$)
- $\text{AAE}_{532/405} = -0.07$ ($R^2 = 0.44$)
- $\text{AAE}_{781/532} = 2.07$ ($R^2 = 0.39$)
- Average $= 1.03$

\[
\beta_{\lambda} = \left( \frac{\lambda}{\lambda_0} \right)^{-\text{AE}}
\]
PASS3 Ambient and Denuded
Ambient Absorption vs Gasphase

- 1 min ambient data
Ambient Absorption vs CO and CO\textsubscript{2}

- 10 minute ambient data: 405 nm, 532 nm, 781 nm
Ambient Absorption vs CO/CO$_2$
Denuded Extinction: PASS3 and CAPS

- CAPS Extinction at 445 nm (TD line)
- PASS-3 Absorption + Scattering at 405 nm corrected to 445 nm
  - 2\textsuperscript{nd} half of the campaign intercomparison
  - All temperatures
  - Initial assumption, lambda = 1 (BC)
  - High $R^2$ 0.985
  - Best fit for lambda = 1.63*
  - EAE from PASS data = 1.1(1.3) ($R^2 = 0.8$)
Extinction: PASS-3 and CAPS

- CAPS Extinction at 450 nm (TD line)
- PASS-3 Absorption + Scattering at 405 nm corrected to 450 nm (assuming \( \lambda = 1 \))
  - Appears to agree well after 1/29
  - Prior to then CAPS is often higher than PASS
Absorption Ratio AMB/TD for all 4 Temperatures
Absorption Enhancement?
Little W of Power Plant w High Winds – not sure (Jan 31- Feb 1)
London Outflow (Feb 3-4)
Kingsnorth Power Station (Feb 10)
Background

- Most aerosols cool the atmosphere by scattering radiation
- Absorbing aerosols, e.g. black carbon (BC) from combustion and hematite in dust, absorb radiation
  - → warming the atmosphere
- BC = most uncertain factor in global warming
Instrumentation

- **SP2**: Direct, online measurement of Black Carbon (BC) mass
  - Single particle incandescence and scattering
    - Highly sensitive: LOD \( \leq 10 \text{ ng/m}^3 \) (< 0.4/cm³)
    - BC size (derived from mass: Approx. 50-700 nm)

- **PASS**: Direct, online measurement of absorption and scattering
  - 375, 405, 532, 781 nm wavelengths
  - Aerosol Absorption and Scattering coefficients \((B_{\text{abs}}, B_{\text{sca}})\)
  - Single Scatter Albedo (SSA)

  - Wavelength-dependent mass absorption coefficients (MAC’s)

  \[
  \text{MAC}(\lambda) = \frac{B_{\text{abs}}(\lambda)}{m_{\text{BC}}}
  \]
Mass Absorption Coefficients (MAC’s)

- Cross et al., ACP, 2010
- Propane soot: Fresh fractal, uncoated (denuded)

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>MAC</th>
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<tbody>
<tr>
<td>781</td>
<td>4.16 m² g⁻¹</td>
</tr>
<tr>
<td>532</td>
<td>8.11 m² g⁻¹</td>
</tr>
<tr>
<td>405</td>
<td>10.0 m² g⁻¹</td>
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- Internal mixtures (coatings)
- External mixtures (brown carbon)
- Internal and External