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: CO_2, H_2O, CH_4

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

ClearfLo

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_2O, CH_4

Kent Showground (Detling)

- **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

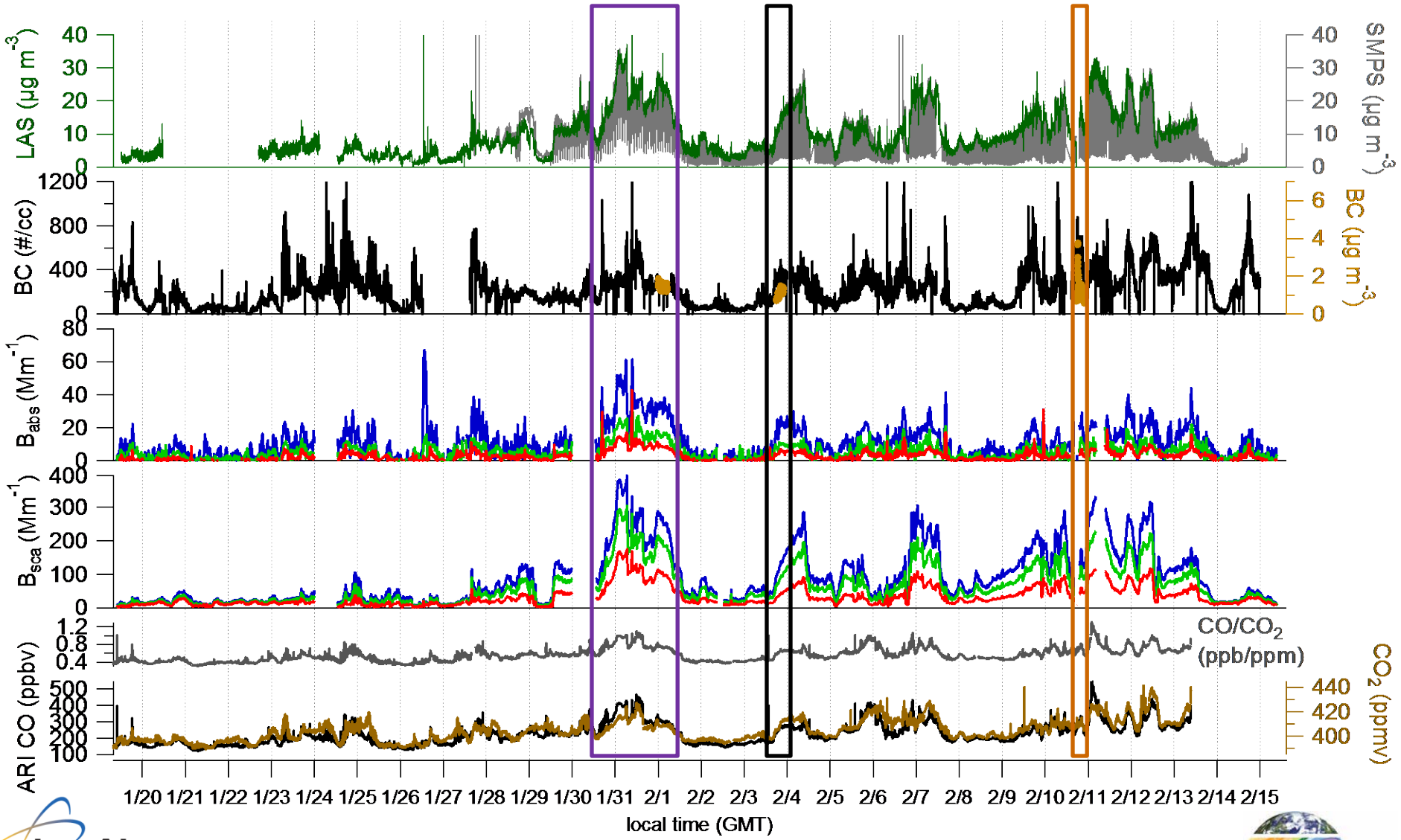
North Kensington

Time Series

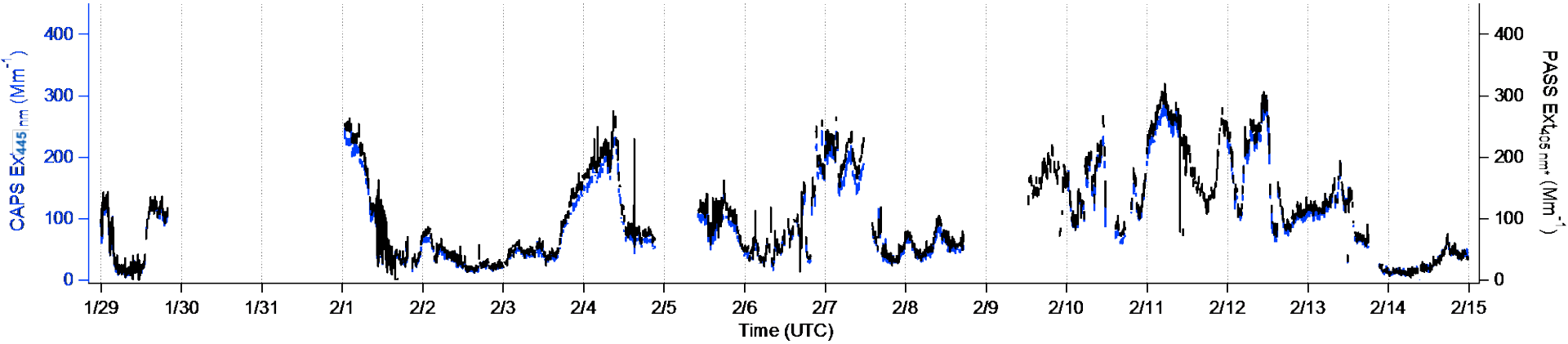
EUR? Outflow

London Outflow

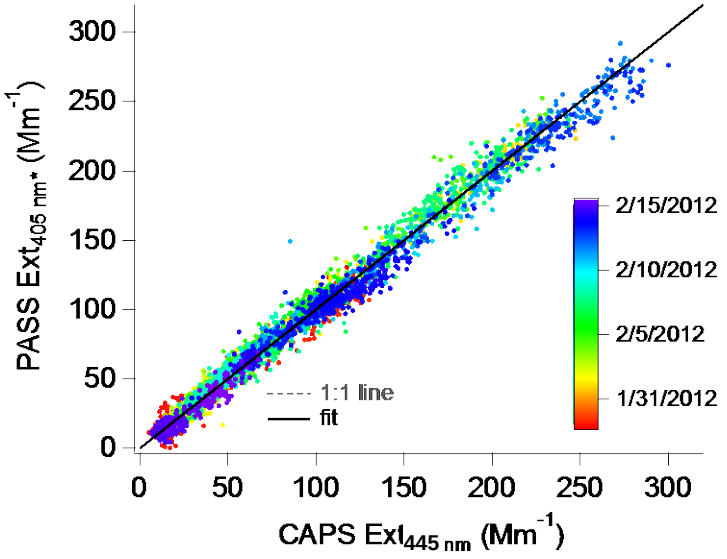
Kingsnorth Power Station



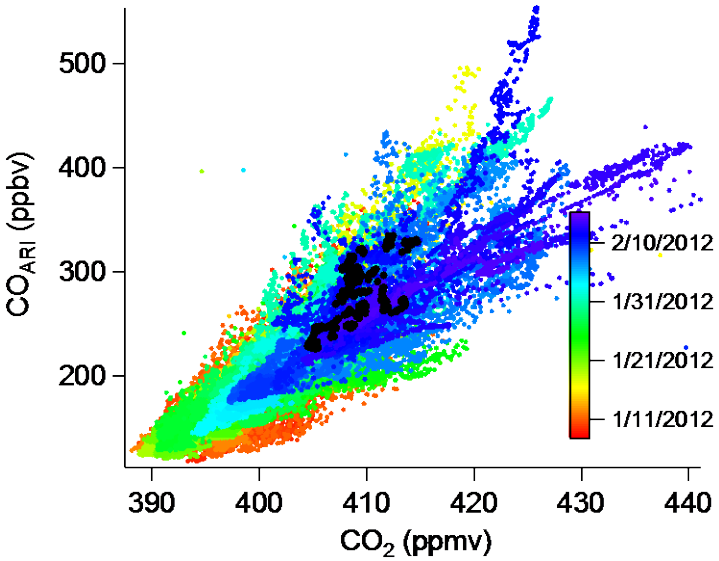
Extinction = Absorption + Scattering? CAPS and PASS3

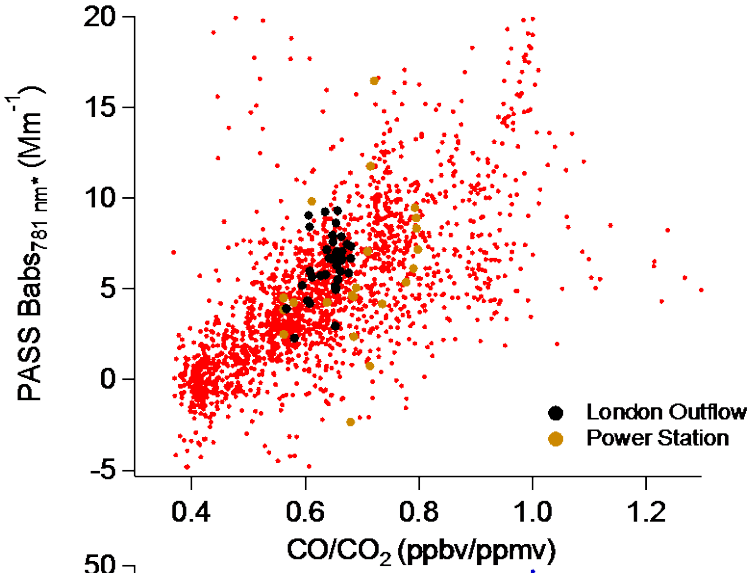


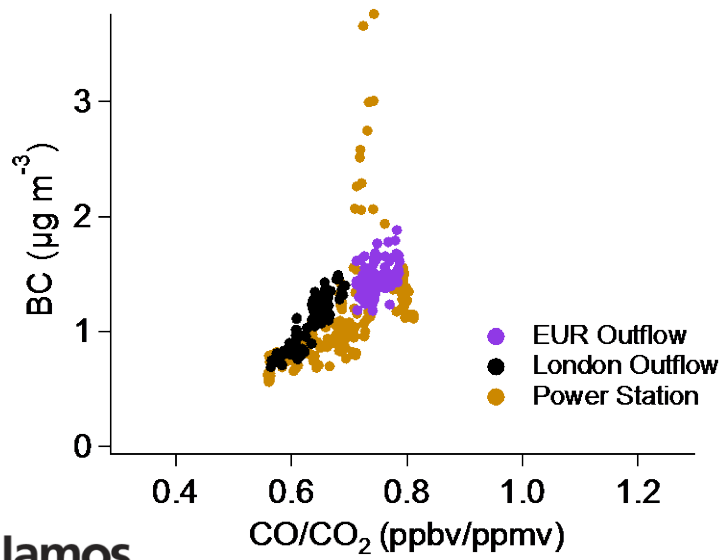
- **CAPS Extinction at 445 nm (TD line)**
- **PASS-3 Absorption + Scattering at 405 nm corrected to 445 nm**
  - 2nd half of the campaign intercomparison
  - EAE from PASS data = 1.8 (R^2 = 0.8)
  - Good first comparison of CAPS and PASS
  - Need to determine EAE from CAPS data

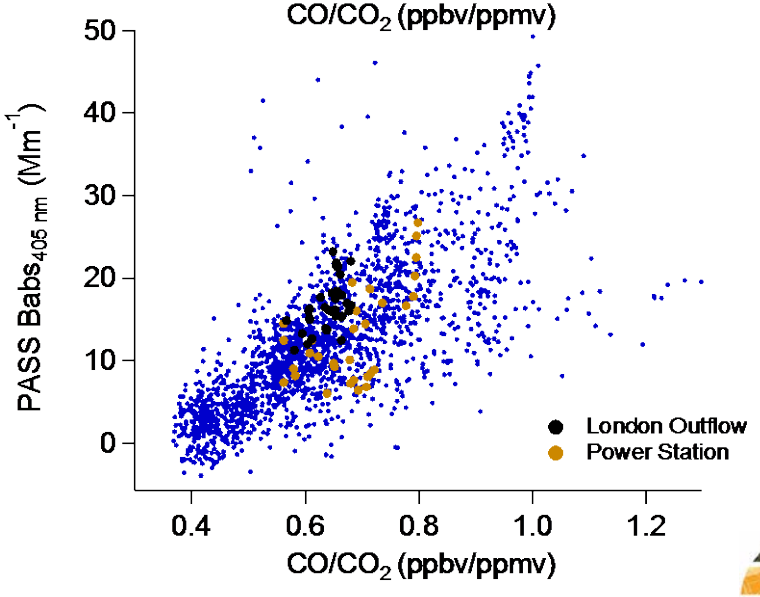


BC Increases with Incomplete Combustion (CO/CO_2)

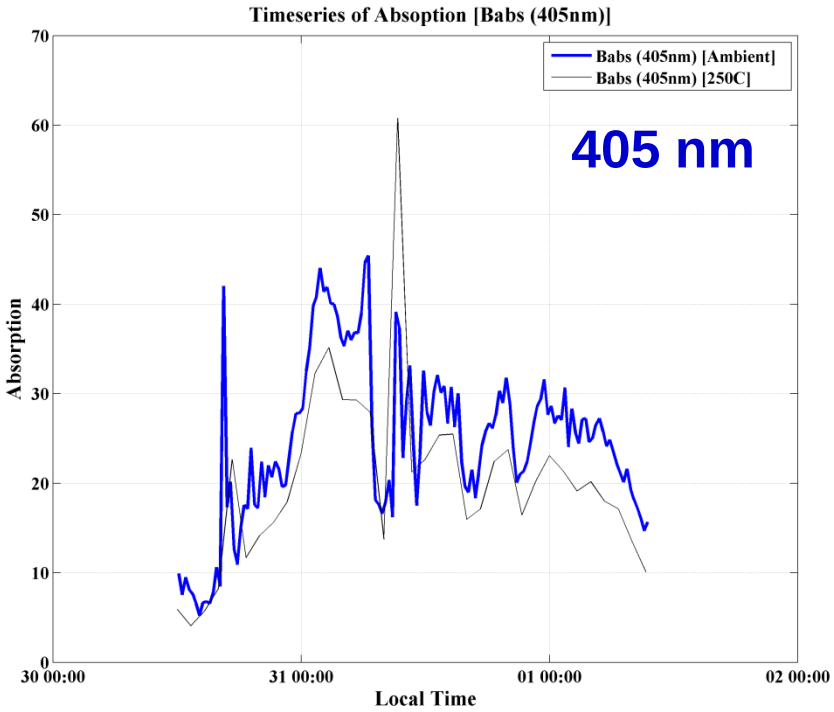


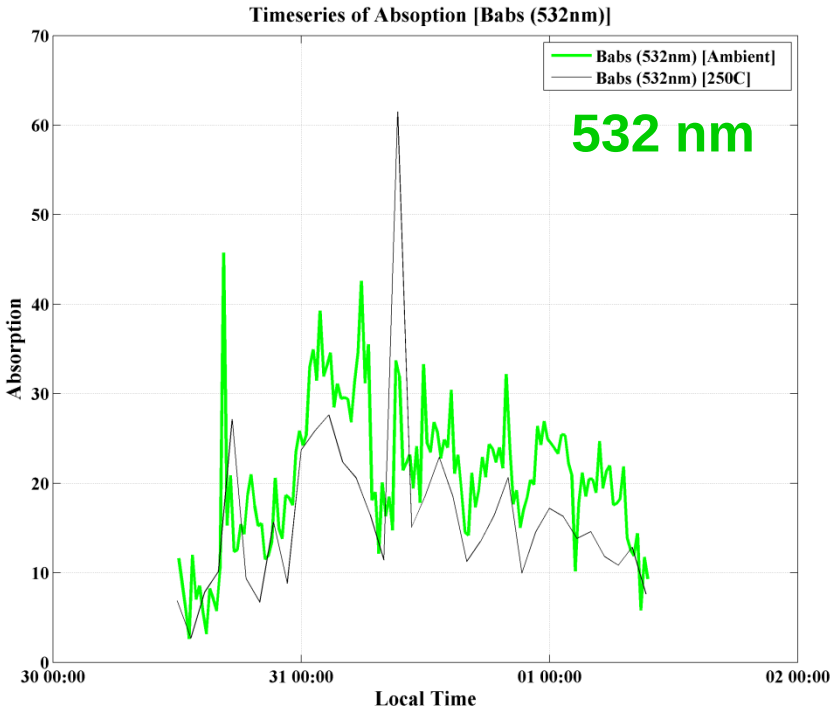


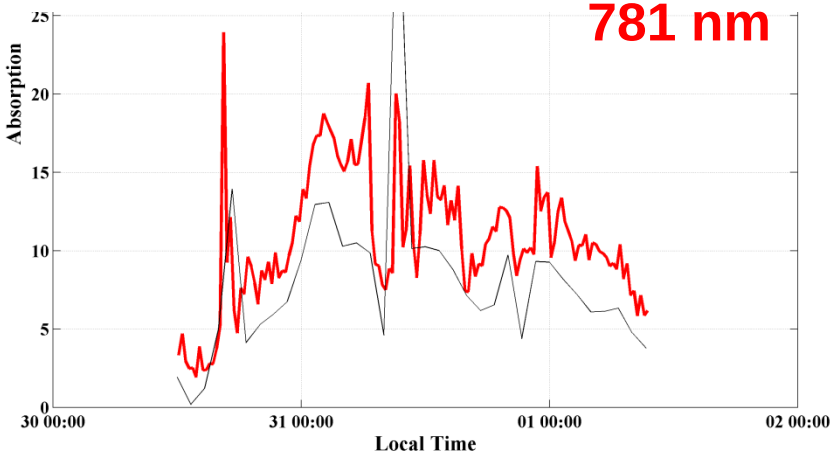




Absorption Enhancement? Ambient vs 250^{0}C TD







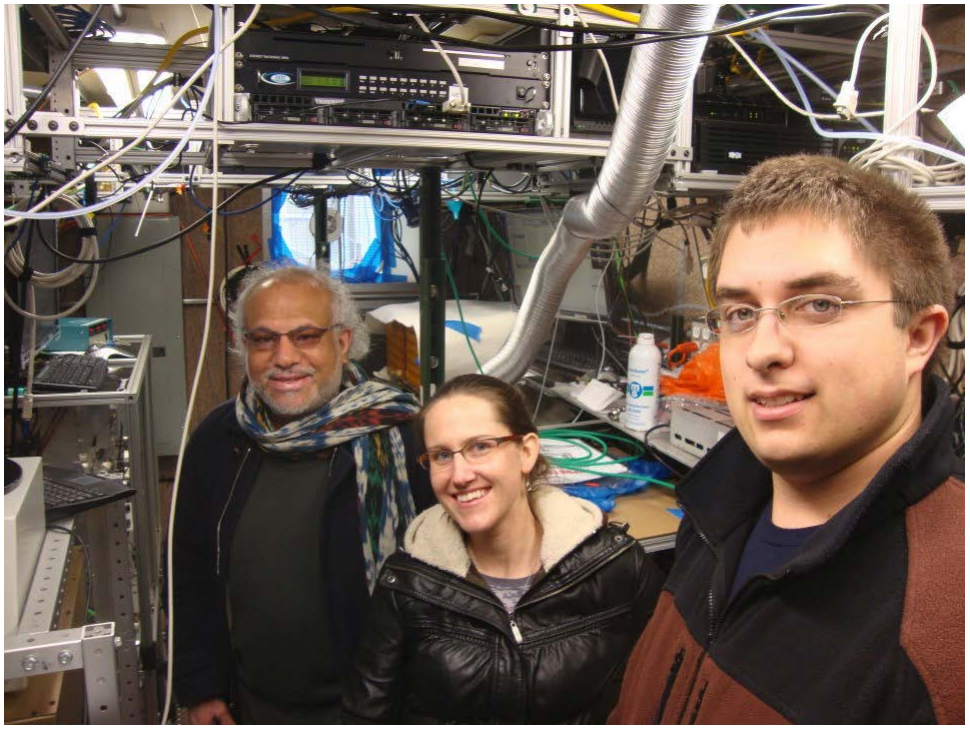
- Need to be corrected for TD losses (Huffman et al.)
- Will be compared with SP2, SP-AMS
- Scattering enhanced by ~2-10x

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/CO_2)**
- **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)**

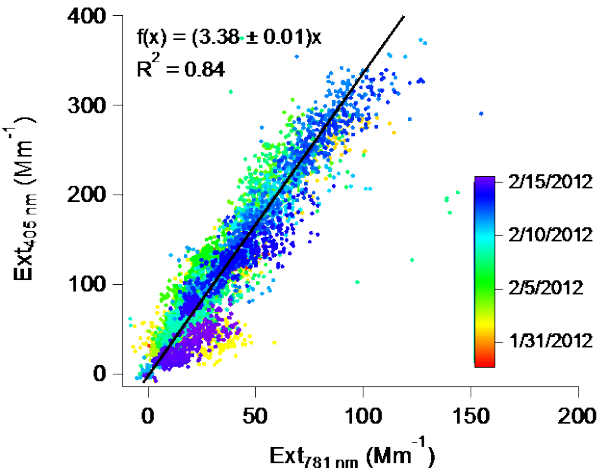
Acknowledgements

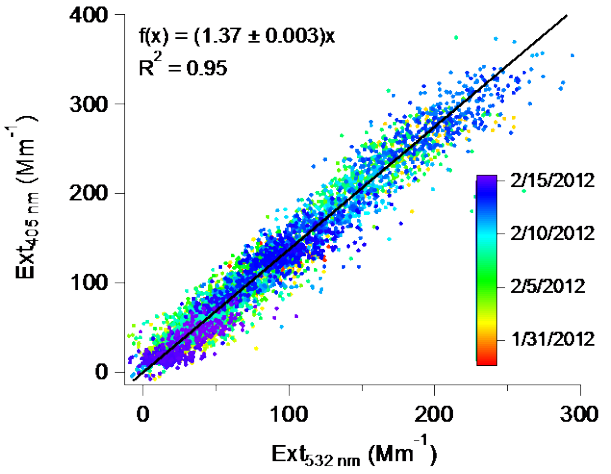
- DOE ASR
- LANL Director's Postdoctoral Fellowship
- ClearfLo
- Kent Showground

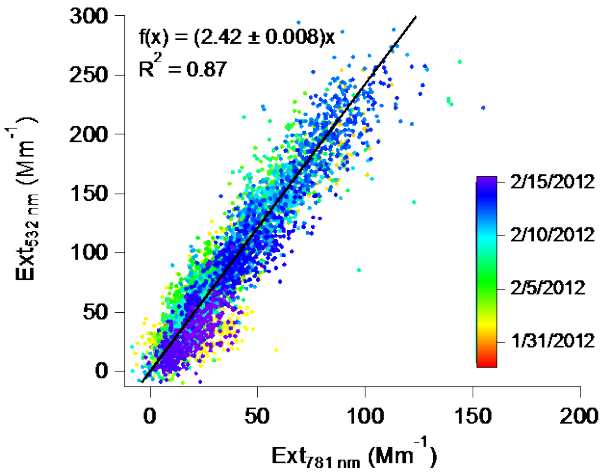


Backup Slides

Ambient PASS3 EAE's



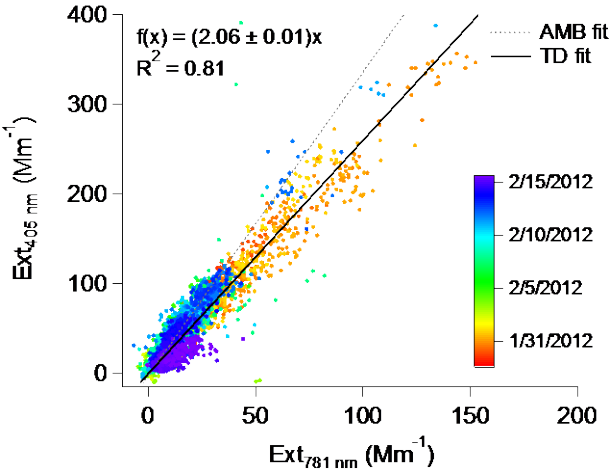


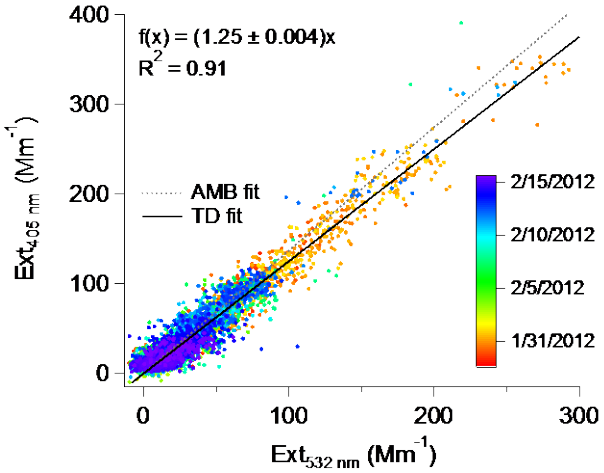


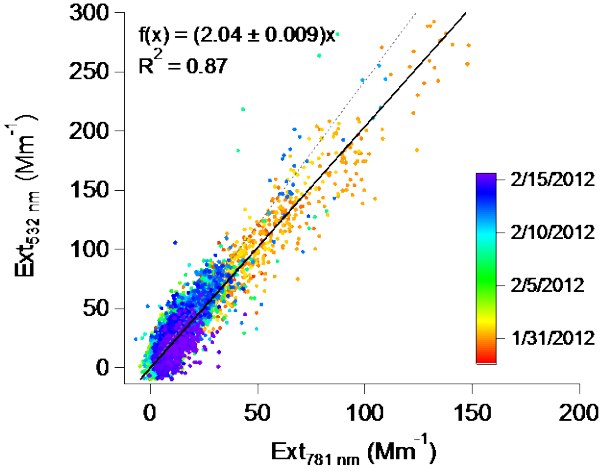
- $EAE_{781/405}$ = 1.85 (R^2 = 0.84)
- $EAE_{532/405}$ = 1.15 (R^2 = 0.95)
- $EAE_{781/532}$ = 2.30 (R^2 = 0.87)
- Average = 1.77

$$\frac{\beta_\lambda}{\beta_{\lambda 0}} = \left(\frac{\lambda}{\lambda_0}\right)^{-AE}$$

TD (all Temperatures) PASS3 EAE's



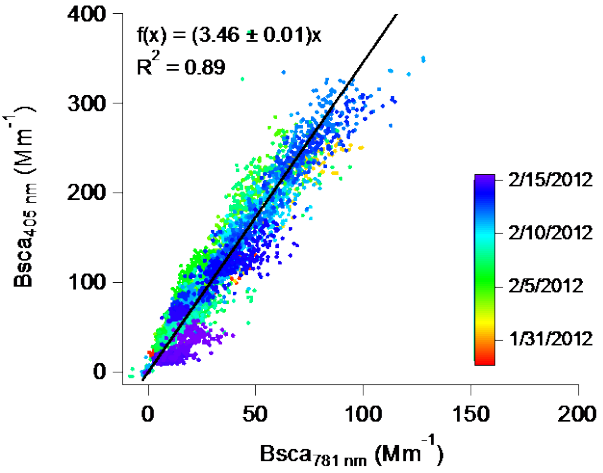


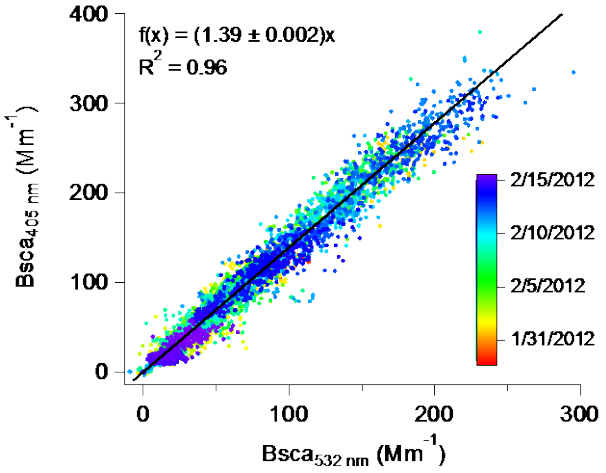


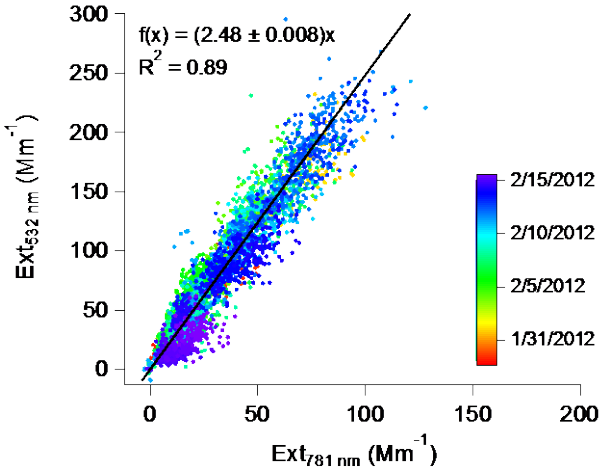
- $EAE_{781/405} = 1.10$ ($R^2 = 0.81$)
- $EAE_{532/405} = 0.82$ ($R^2 = 0.91$)
- $EAE_{781/532} = 1.86$ ($R^2 = 0.87$)
- Average = 1.3

$$\frac{\beta_\lambda}{\beta_{\lambda 0}} = \left(\frac{\lambda}{\lambda_0}\right)^{-AE}$$

Ambient PASS3 SAE's



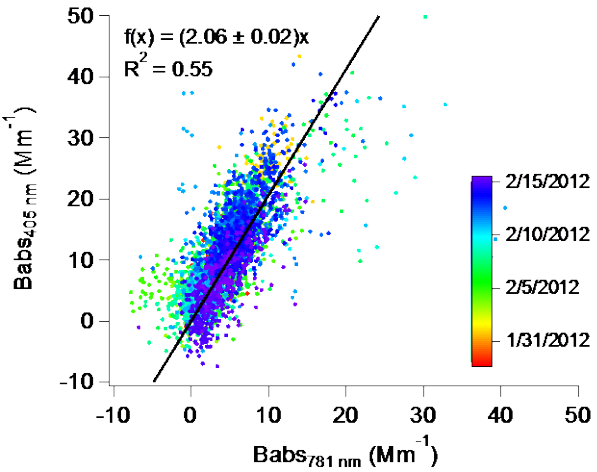


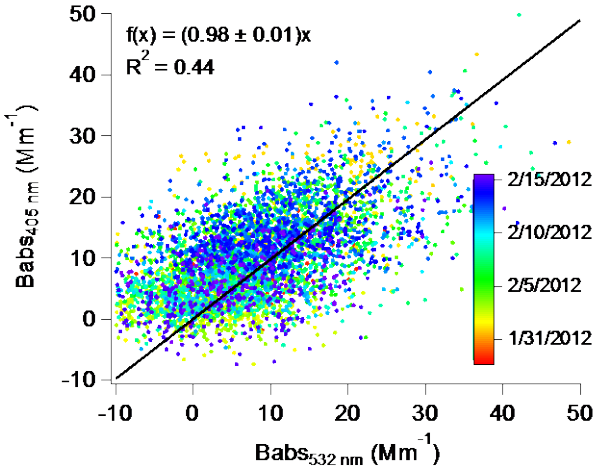


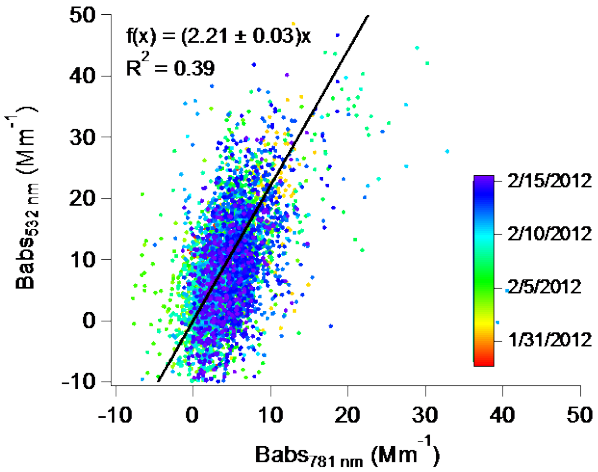
- $SAE_{781/405} = 1.89 (R^2 = 0.89)$
- $SAE_{532/405} = 1.21 (R^2 = 0.96)$
- $SAE_{781/532} = 2.37 (R^2 = 0.89)$
- Average = 1.82

$$\frac{\beta_\lambda}{\beta_{\lambda 0}} = \left(\frac{\lambda}{\lambda_0}\right)^{-AE}$$

Ambient PASS3 AAE's



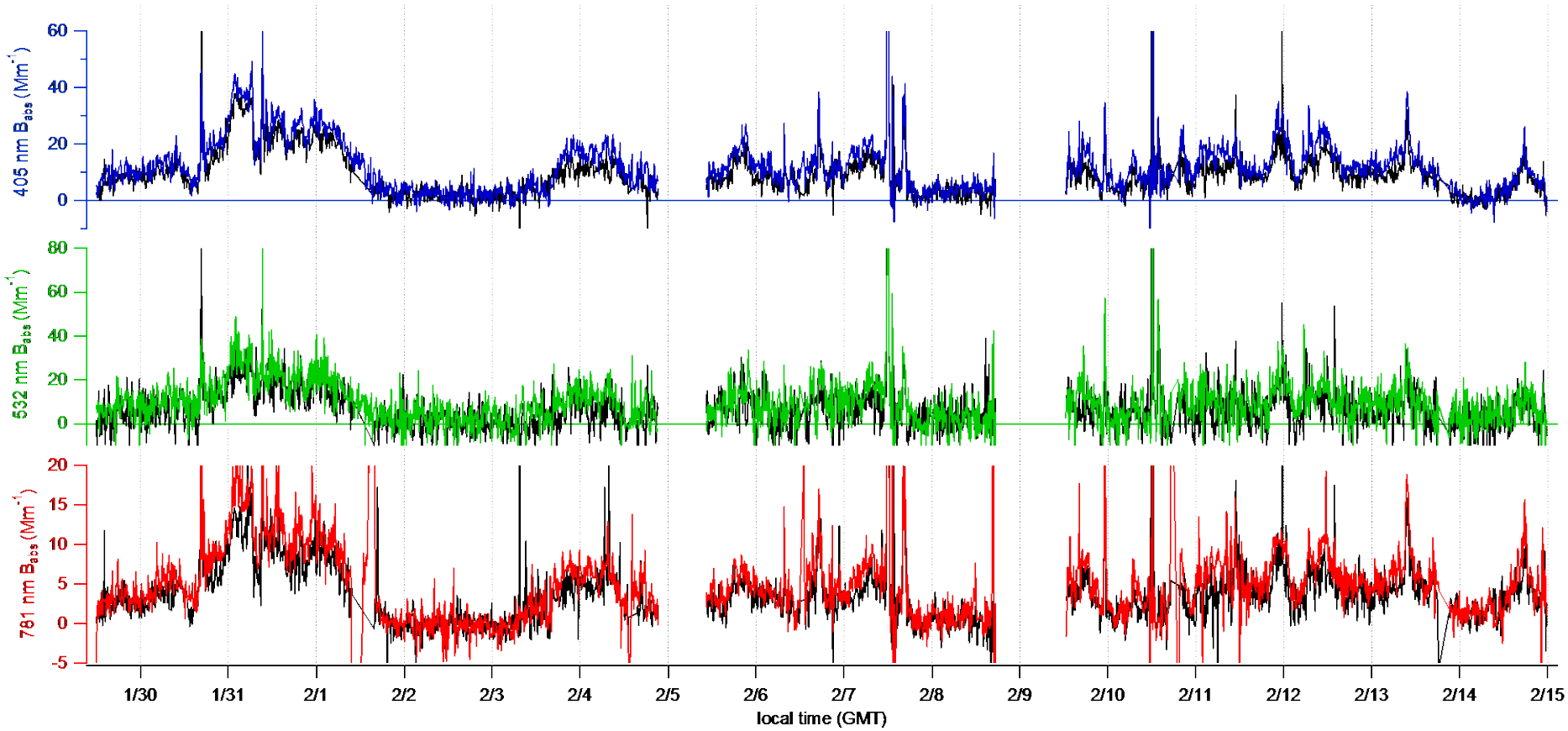




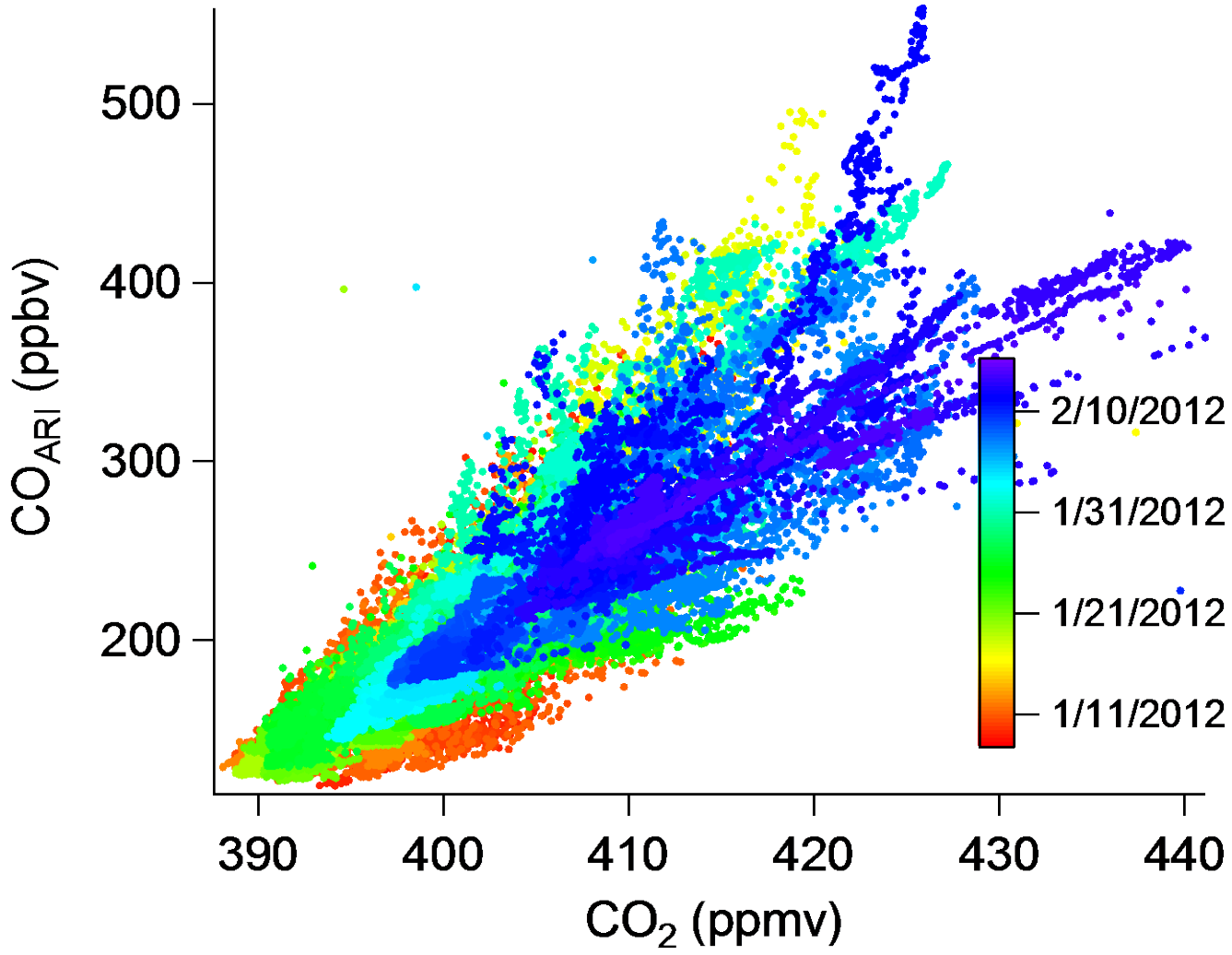
- $AAE_{781/405}$ = 1.10 (R^2 = 0.55)
- $AAE_{532/405}$ = -0.07 (R^2 = 0.44)
- $AAE_{781/532}$ = 2.07 (R^2 = 0.39)
- Average = 1.03

$$\frac{\beta_\lambda}{\beta_{\lambda 0}} = \left(\frac{\lambda}{\lambda_0}\right)^{-AE}$$

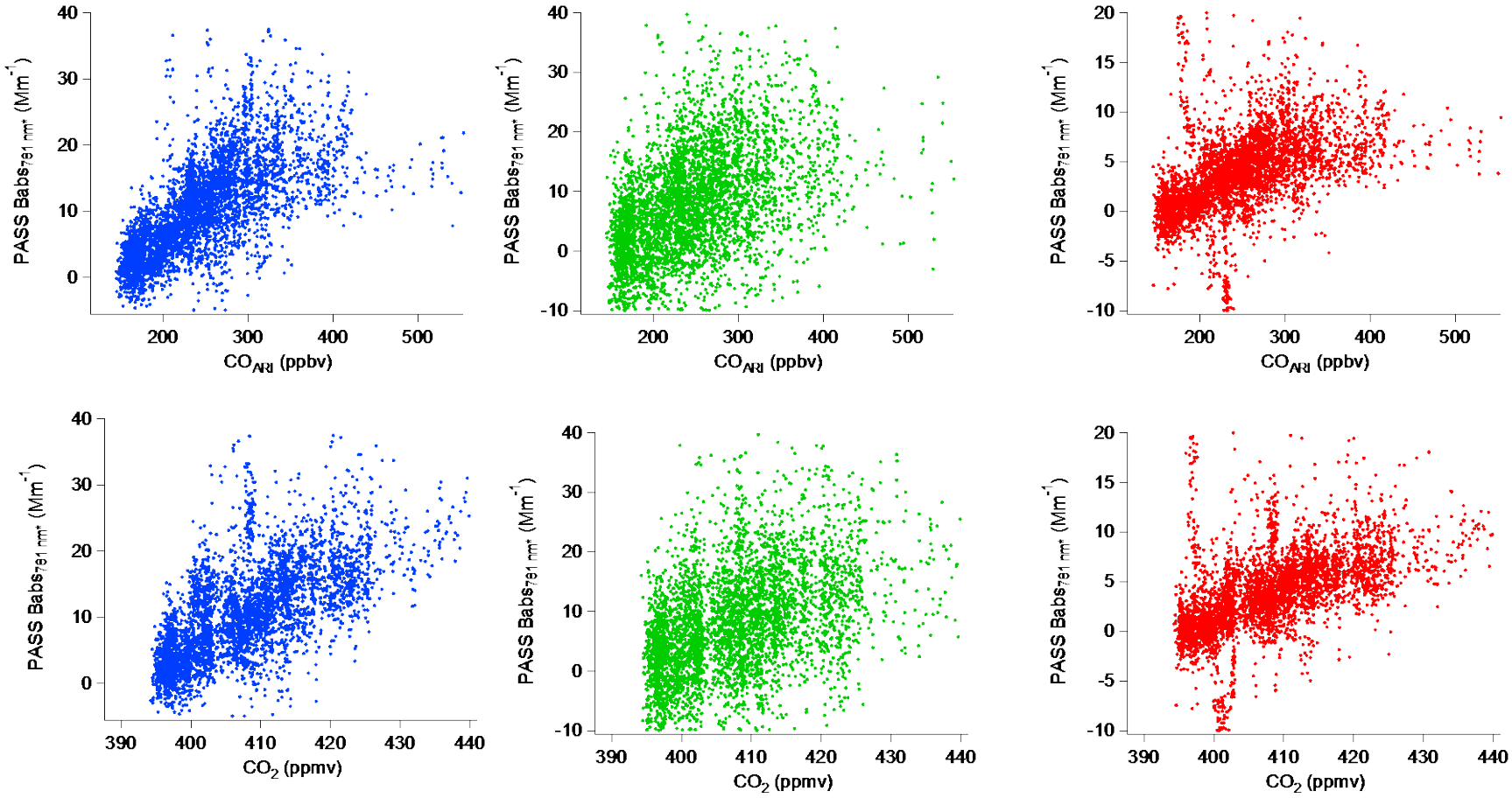
PASS3 Ambient and Denuded



CO vs CO_2

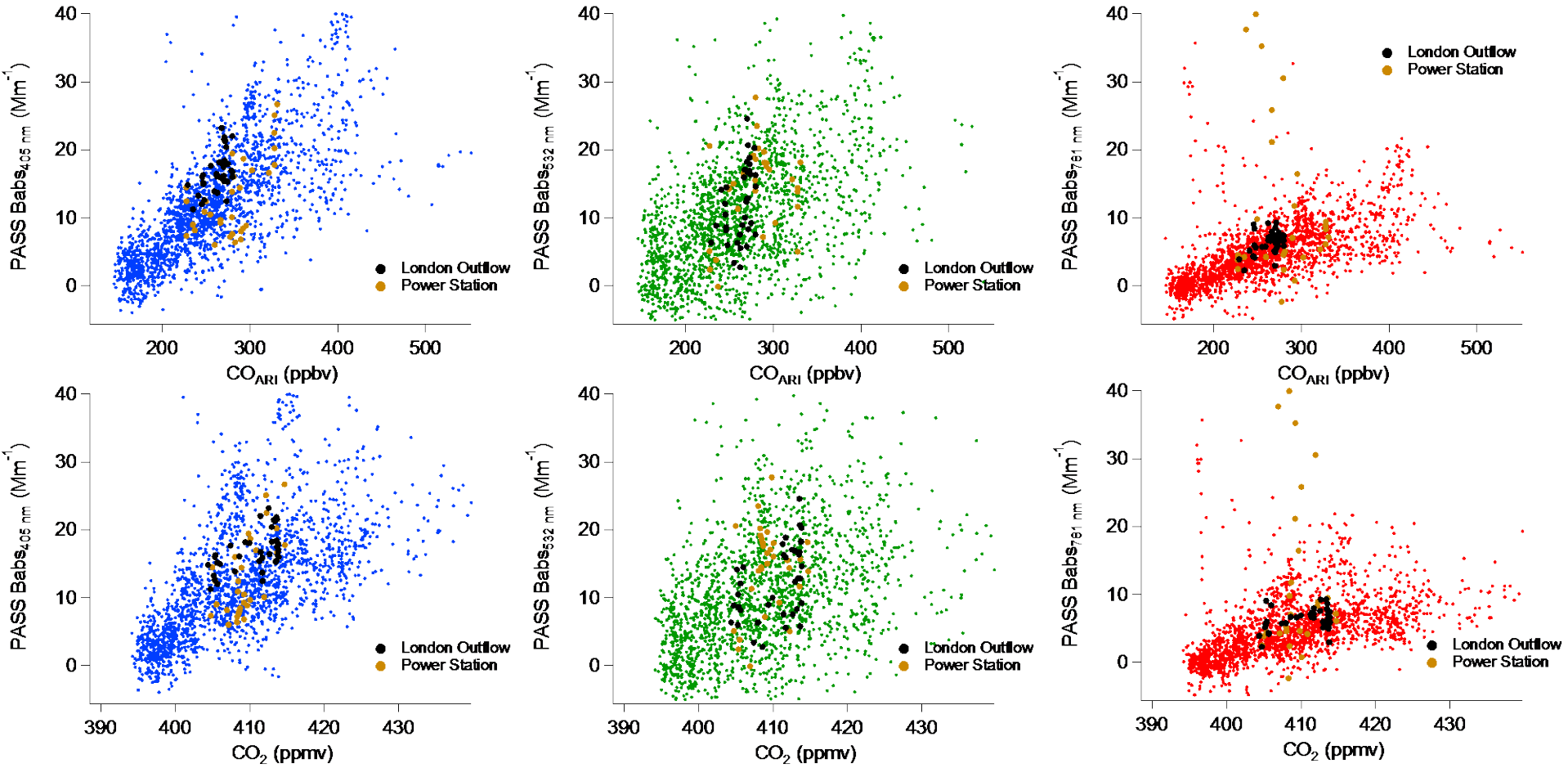

500
400
300
200
CO_{ARI} (ppbv)
390
400
410
420
430
440
CO_2 (ppmv)
2/10/2012
1/31/2012
1/21/2012
1/11/2012

Ambient Absorption vs Gasphase



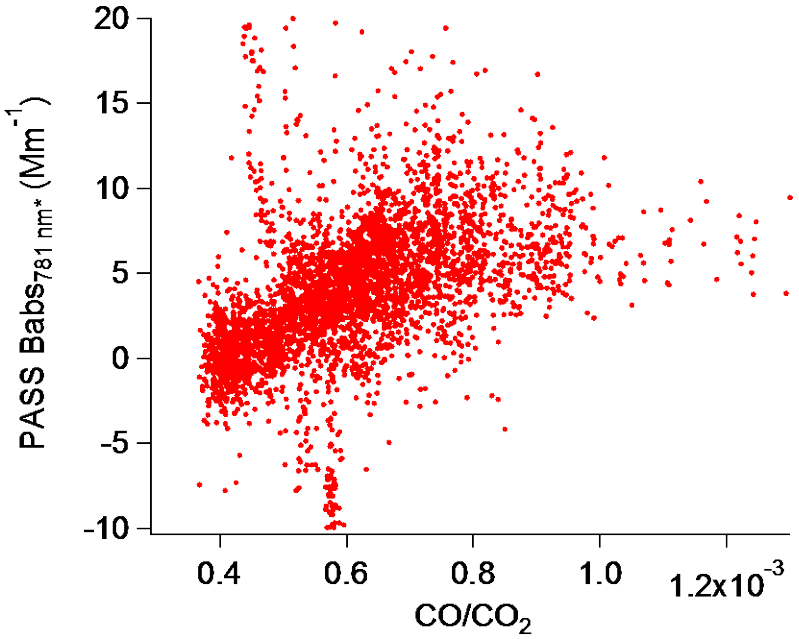
- 1 min ambient data

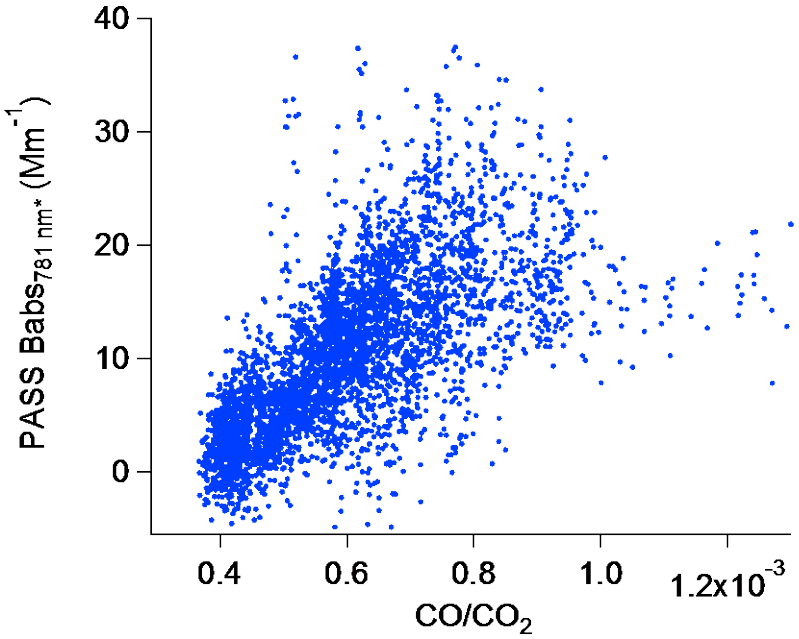
Ambient Absorption vs CO and CO_2



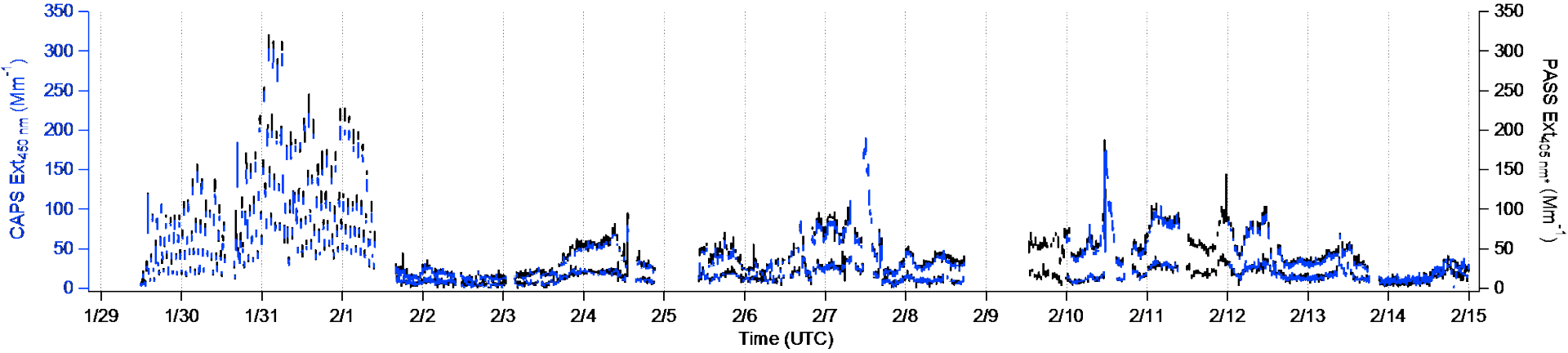
- **10 minute ambient data: 405 nm, 532 nm, 781 nm**

Ambient Absorption vs CO/CO_2

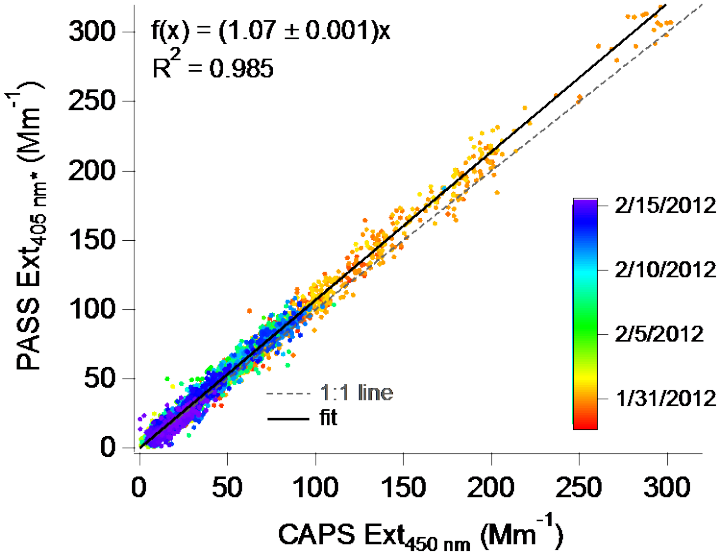




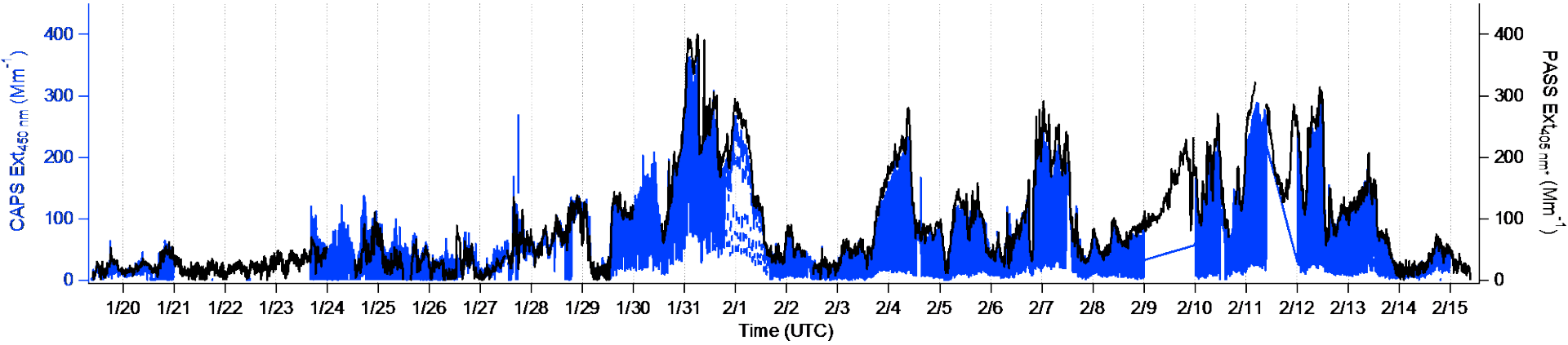
Denuded Extinction: PASS3 and CAPS



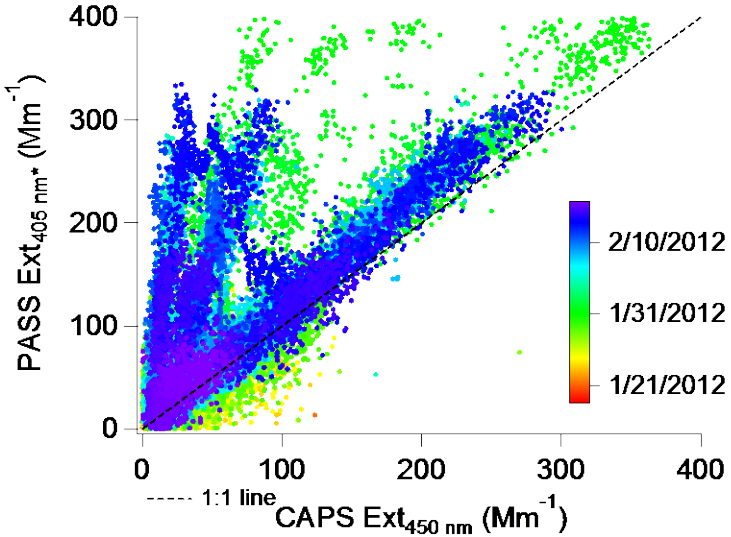
- **CAPS Extinction at 445 nm (TD line)**
- **PASS-3 Absorption + Scattering at 405 nm corrected to 445 nm**
  - 2nd half of the campaign intercomparison
  - All temperatures
  - Initial assumption, lambda = 1 (BC)
  - High R^2 0.985
  - Best fit for lambda = 1.63*
  - EAE from PASS data = 1.1(1.3) (R^2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



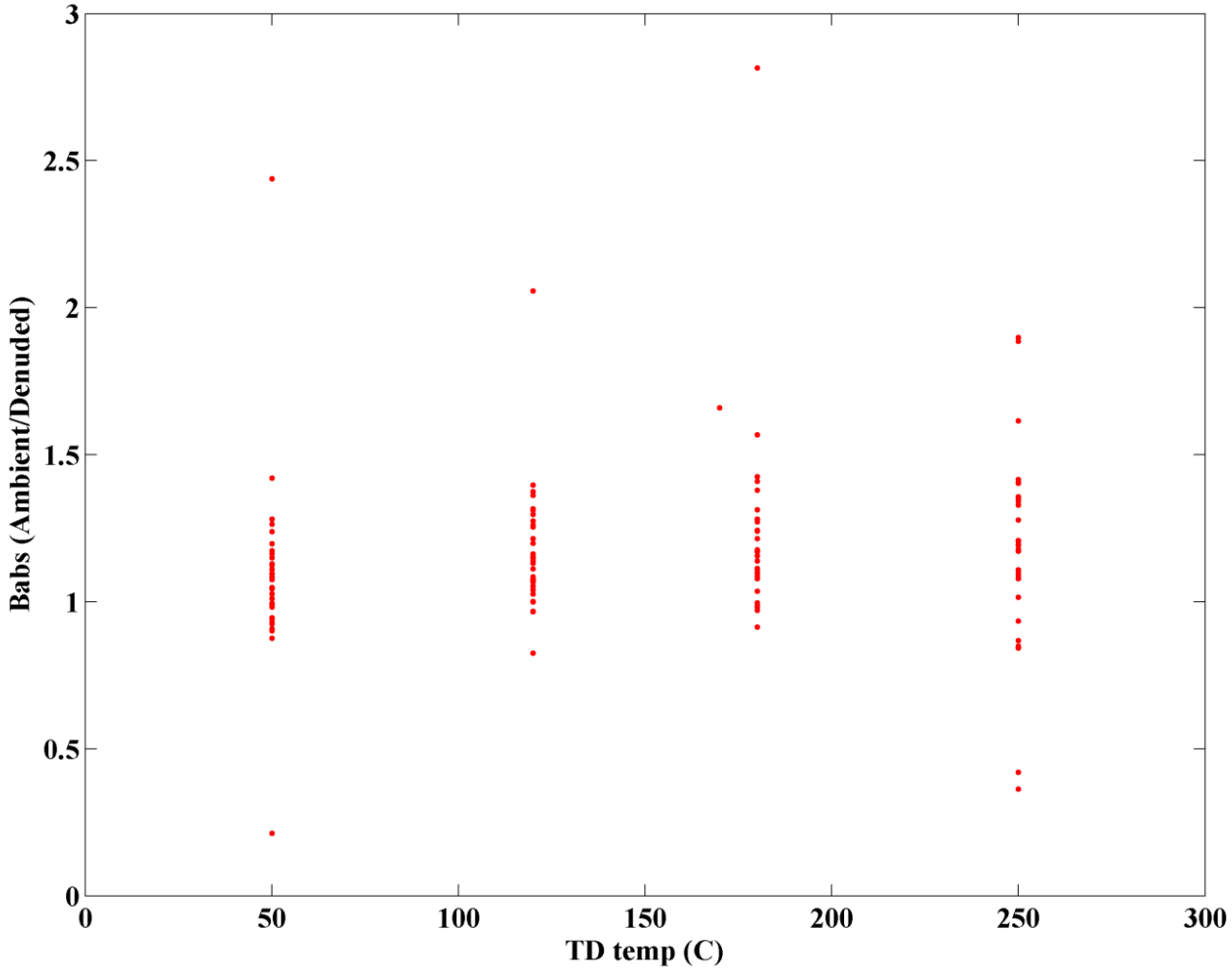
Extinction: PASS-3 and CAPS



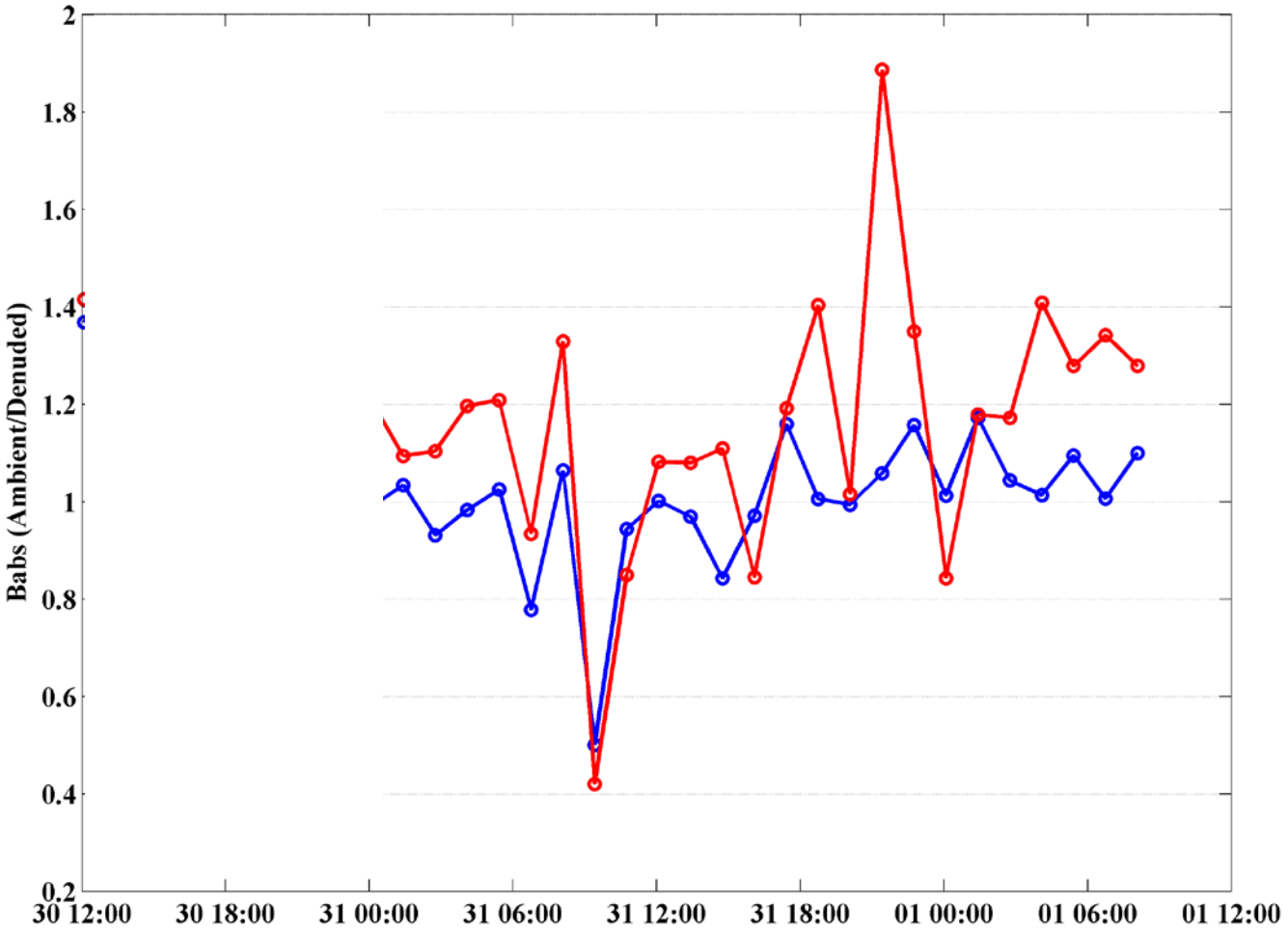
- **CAPS Extinction at 450 nm (TD line)**
- **PASS-3 Absorption + Scattering at 405 nm corrected to 450 nm (assuming lambda = 1)**
  - Appears to agree well after 1/29
  - Prior to then CAPS is often higher than PASS

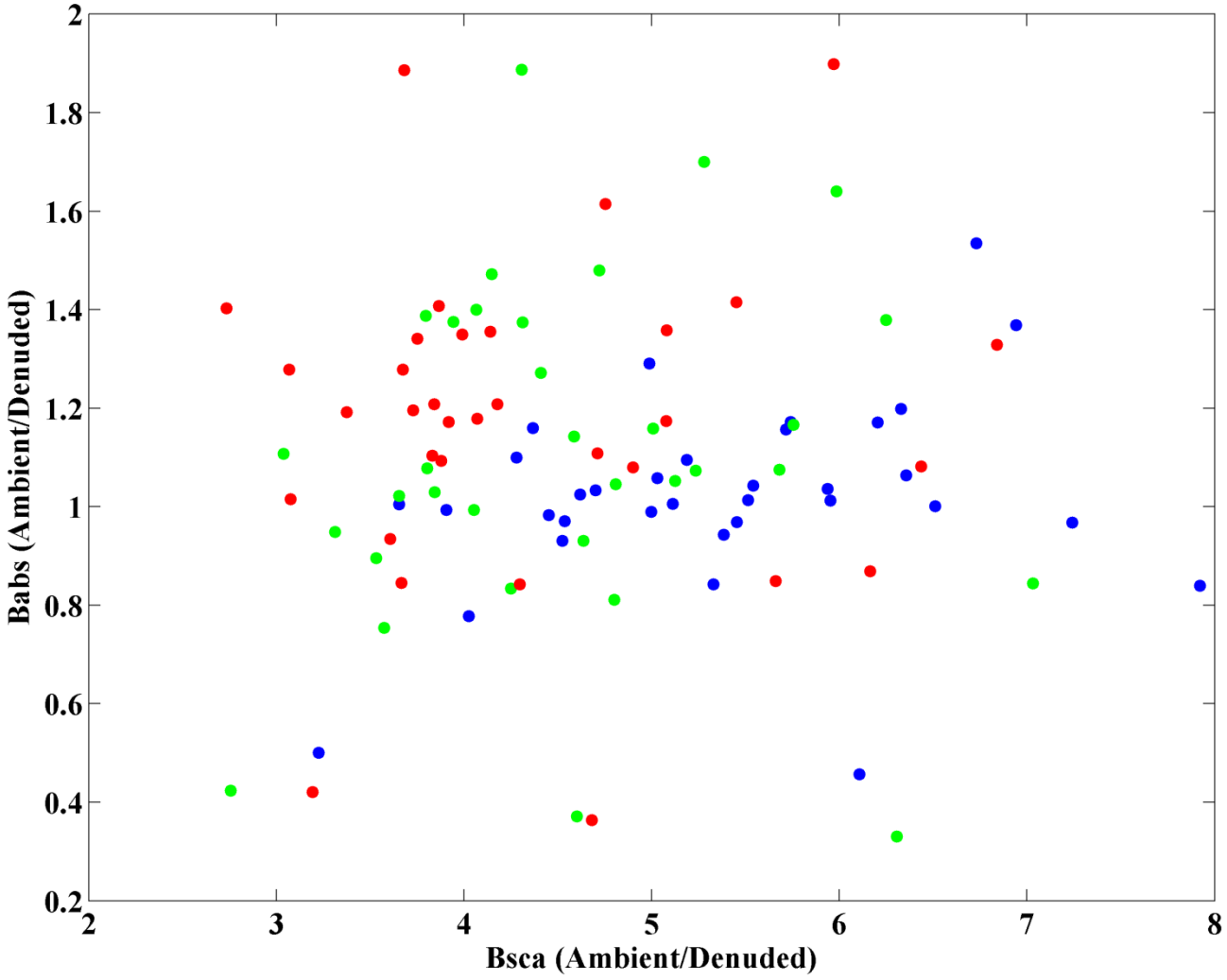


Absorption Ratio AMB/TD for all 4 Temperatures

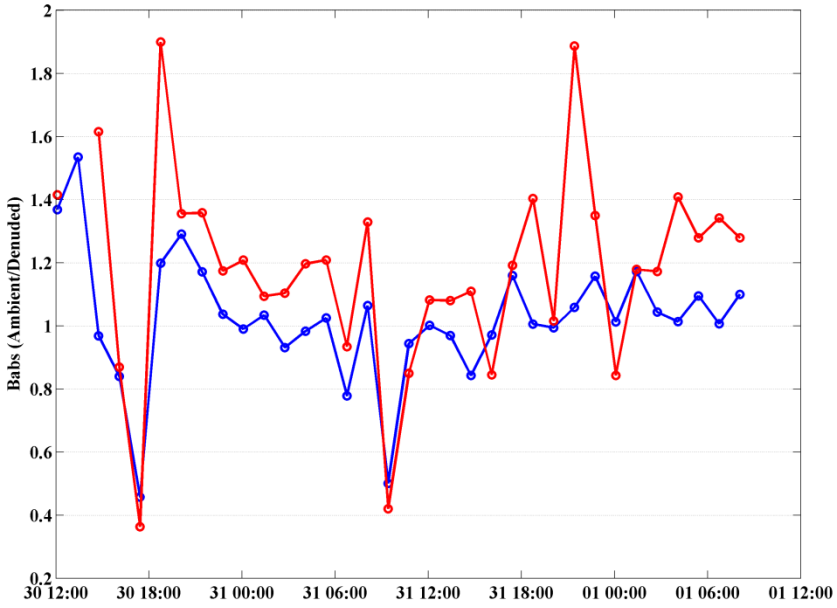


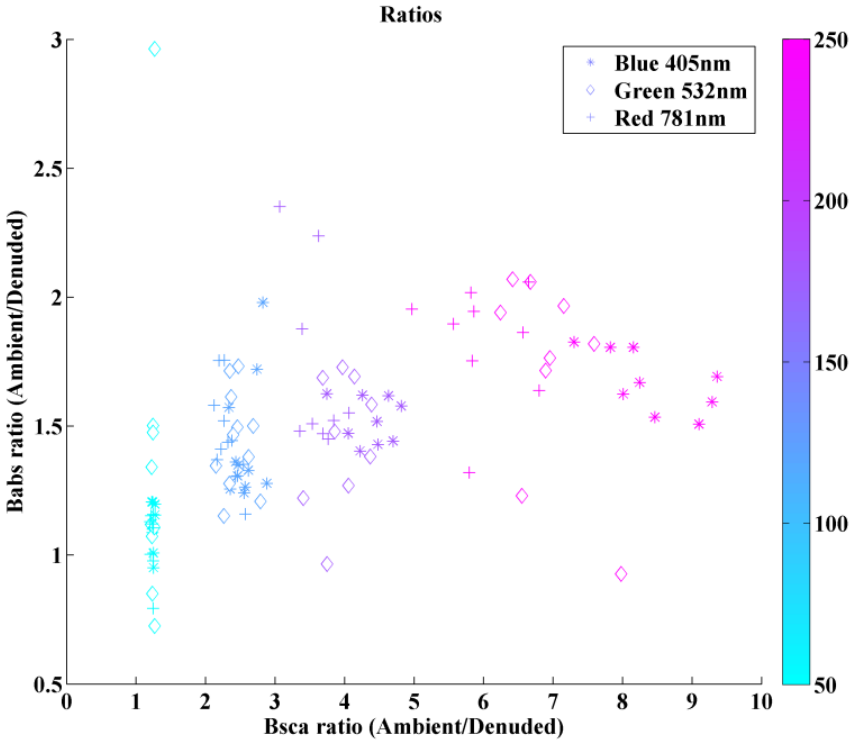
Absorption Enhancement?



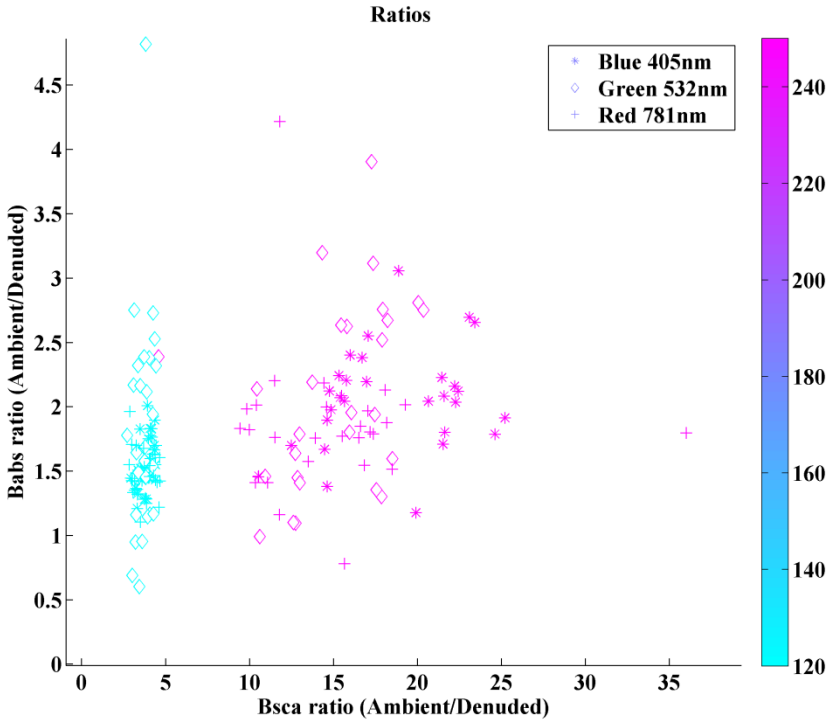


Little W of Power Plant w High Winds – not sure (Jan 31- Feb 1)

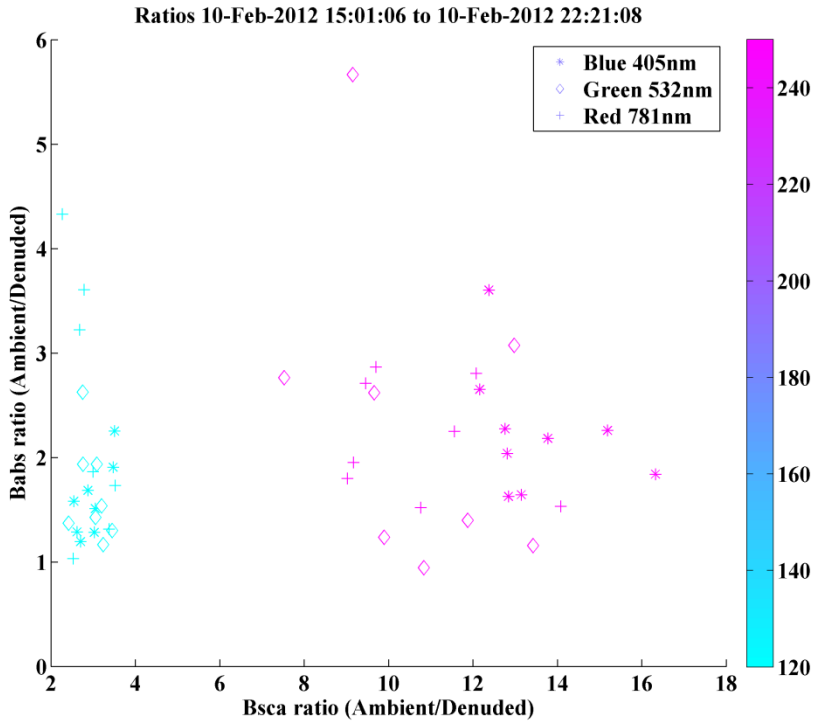




London Outflow (Feb 3-4)

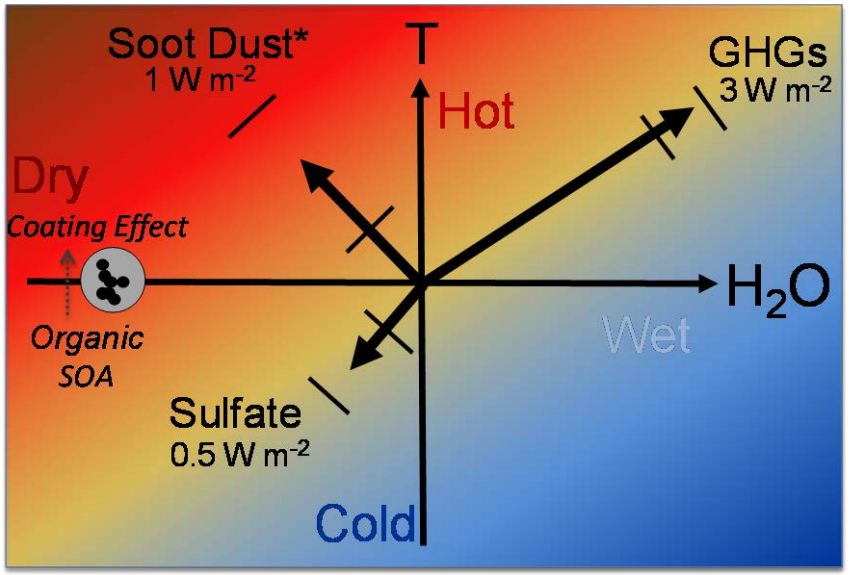


Kingsnorth Power Station (Feb 10)



Background

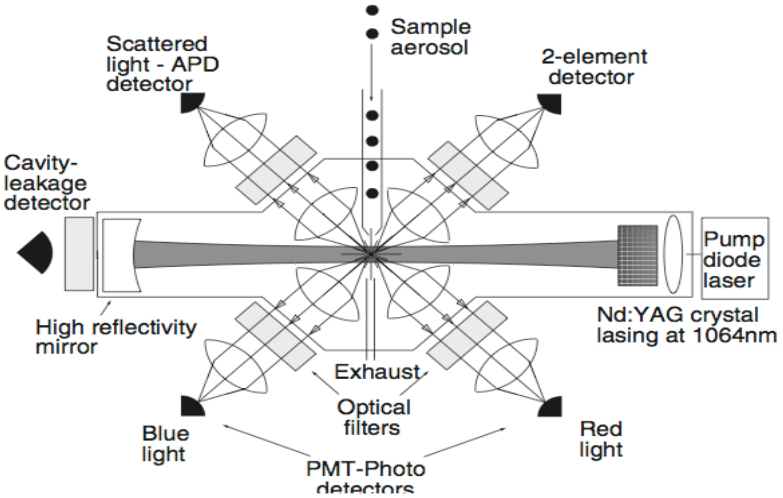
- **Most aerosols cool the atmosphere by scattering radiation**
- **Absorbing aerosols, e.g. black carbon (BC) from combustion and hematite in dust, absorb radiation**
  - → warming the atmosphere



- **BC = most uncertain factor in global warming**

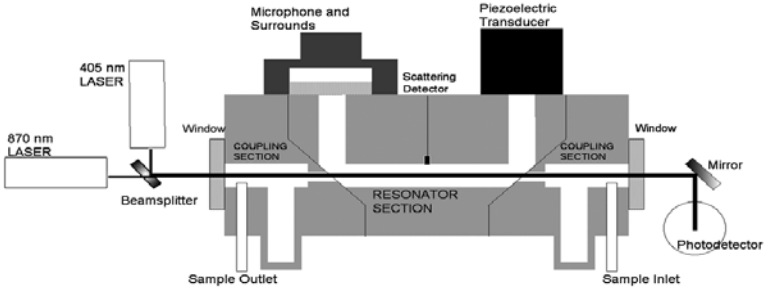
Instrumentation

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



Schwarz, J.P., et al. JGR-A, 111, D16207, 2006.

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



Tian, G., et al. AS&T, 43, 1084-1090, 2009.
Flowers B et al ACP, 2010

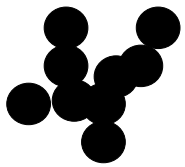
- **Wavelength-dependent mass absorption coefficients (MAC's)**

$$MAC(\lambda) = B_{abs}(\lambda)/m_{BC}$$

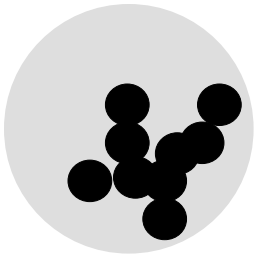
Mass Absorption Coefficients (MAC's)

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

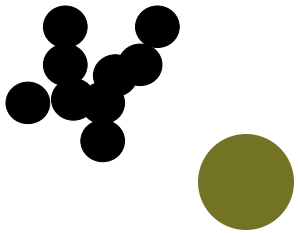
781 nm
532 nm
405 nm



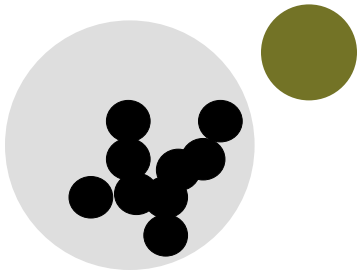
$MAC_{781nm} = 4.16\ m^2\ g^{-1}$
$MAC_{532nm} = 8.11\ m^2\ g^{-1}$
$MAC_{405nm} = 10.0\ m^2\ g^{-1}$



Internal mixtures (coatings)



External mixtures (brown carbon)



Internal and External