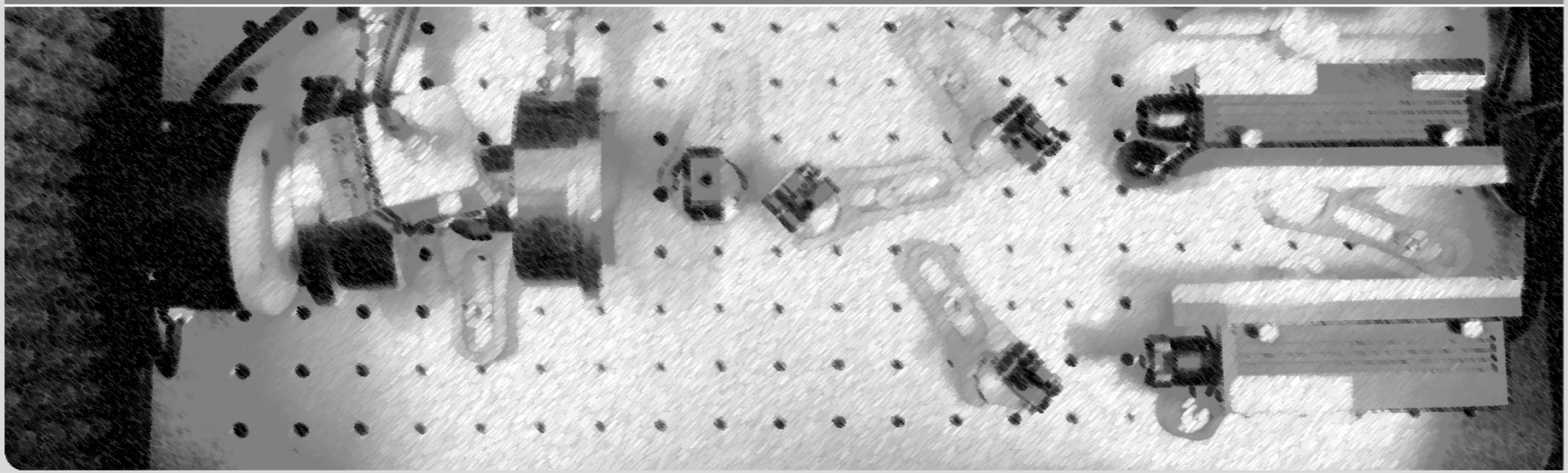
Karlsruhe Institute of Technology

The Spectral Light Absorption Properties of Black and Brown Carbon Using Photoacoustic Spectroscopy

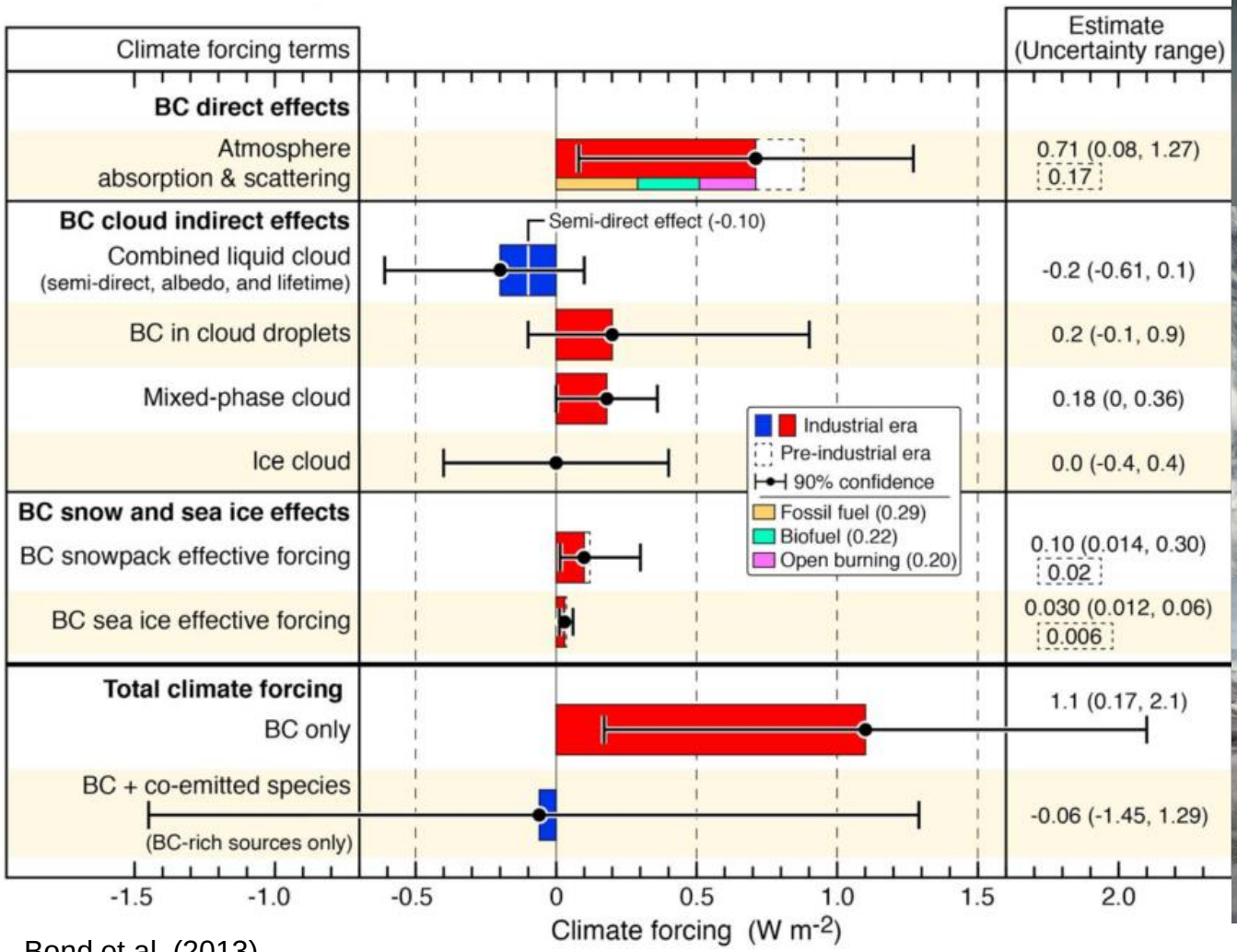
Martin Schnaiter and Claudia Linke

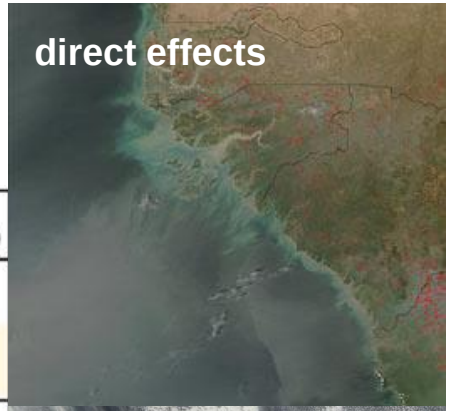
Sino-German Symposium, 28.06.2016

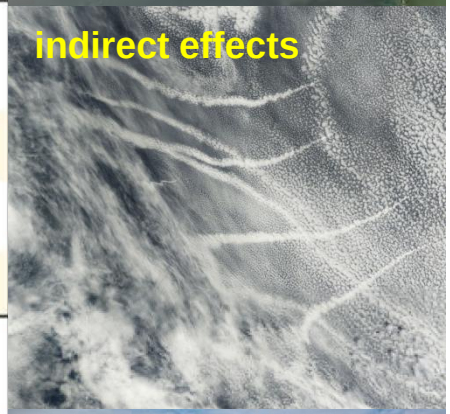
Institute of Meteorology and Climate Research, Atmospheric Aerosol Research



Black Carbon and Climate Change



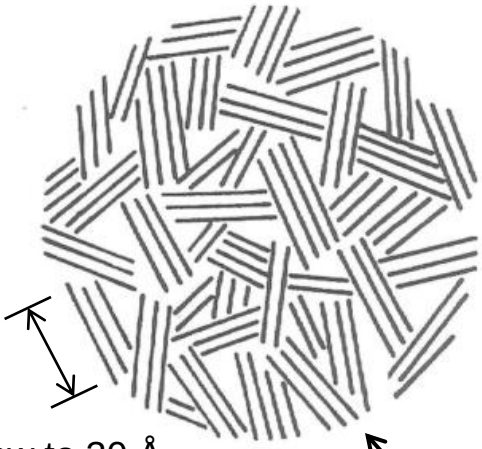




Bond et al. (2013)

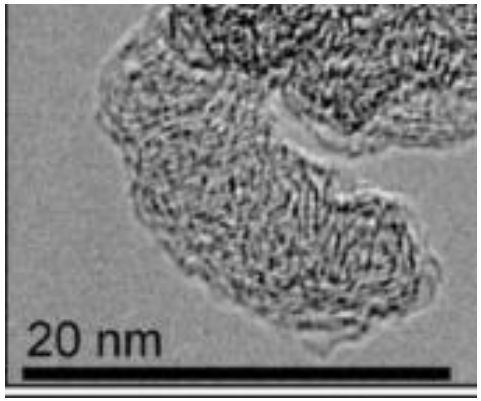
Institute of Meteorology and Climate Research
Atmospheric Aerosol Research

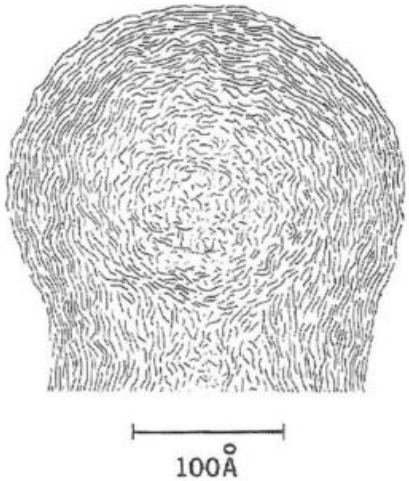
Absorption in Carbonaceous Material – A Solid State Perspective

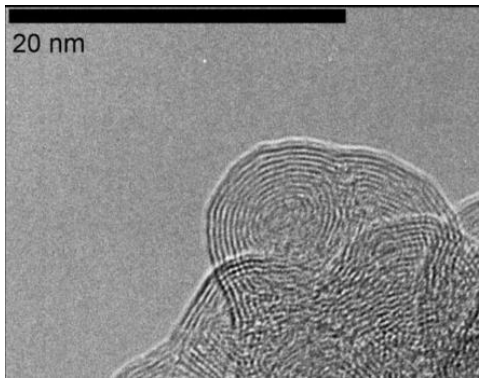


few to 30 Å

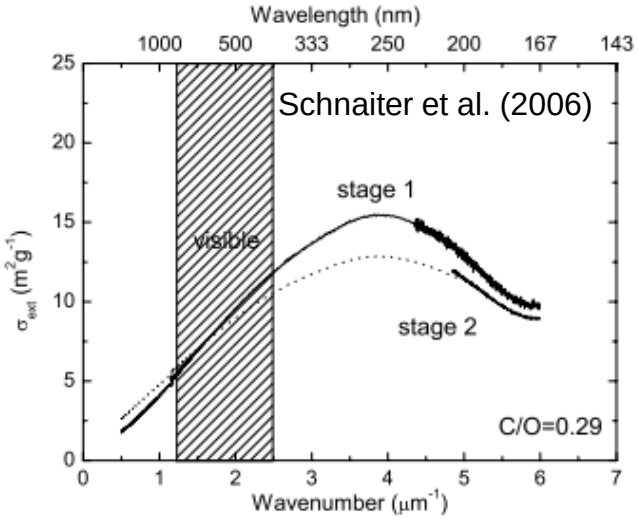
nanocrystalline graphitic regions (BSU)

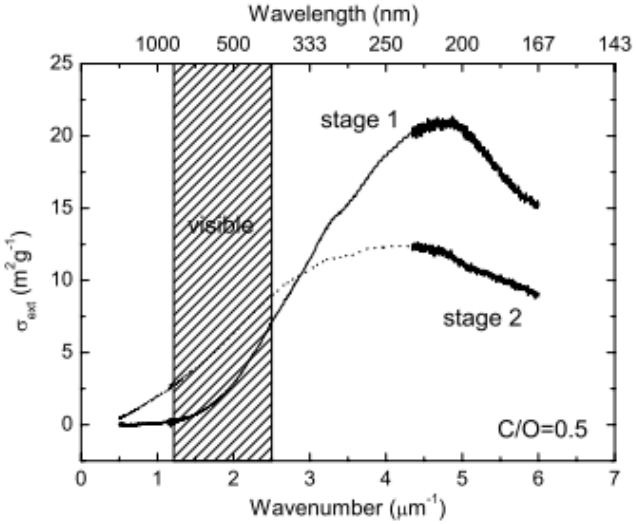






Jäger et al. (1999)



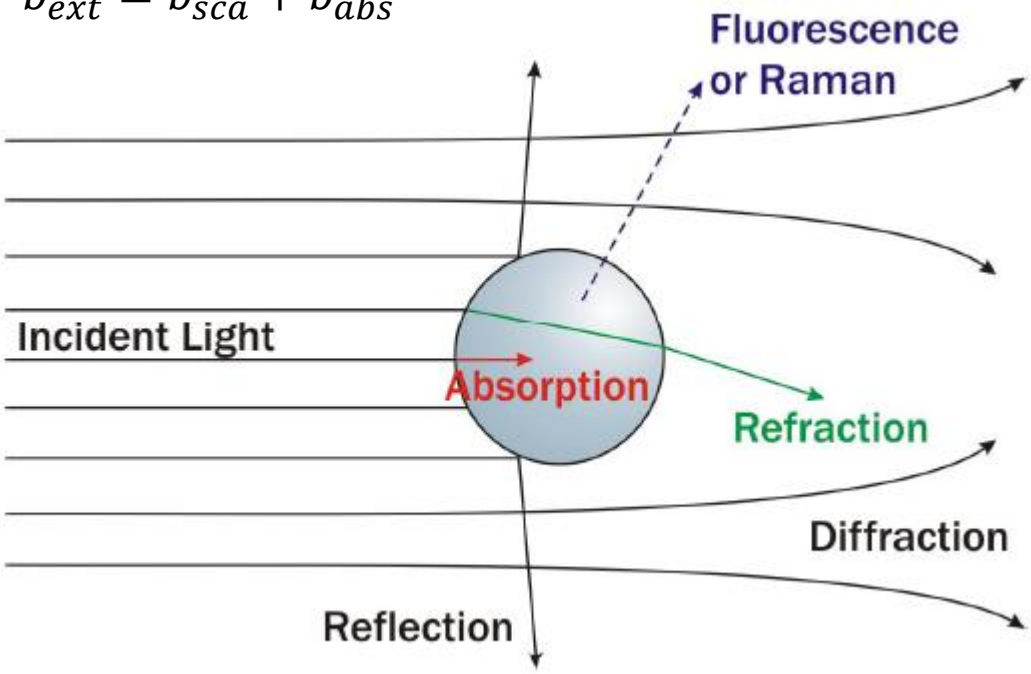


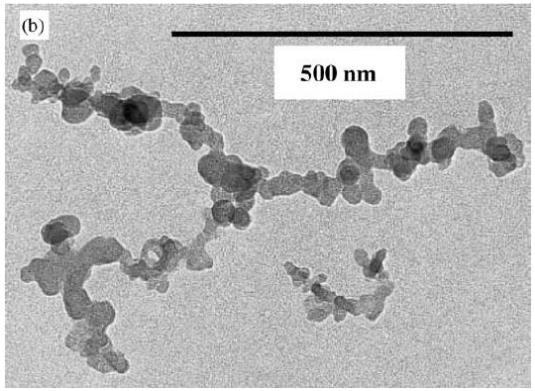
Institute of Meteorology and Climate Research
Atmospheric Aerosol Research

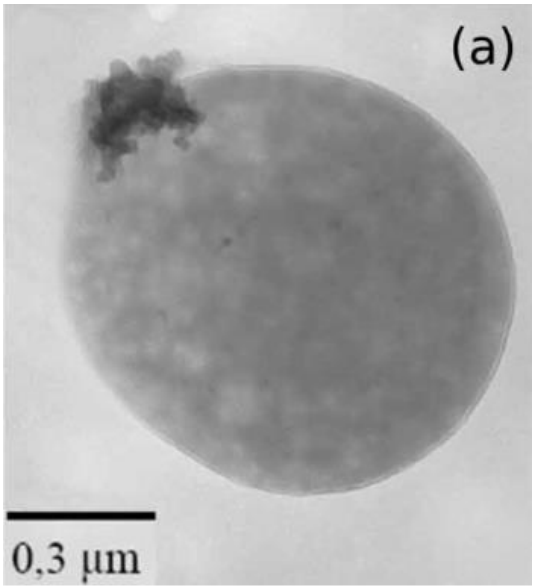
How to Measure Absorption by Particles?

$$\ln\left(\frac{I}{I_0}\right) = -b_{ext} l$$

$$b_{ext} = b_{sca} + b_{abs}$$

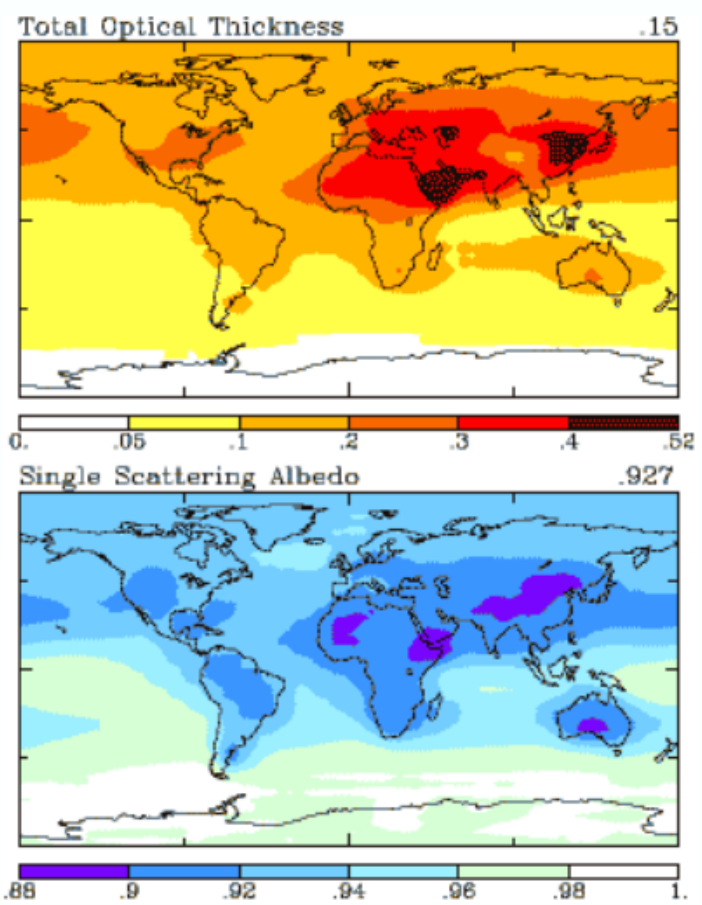






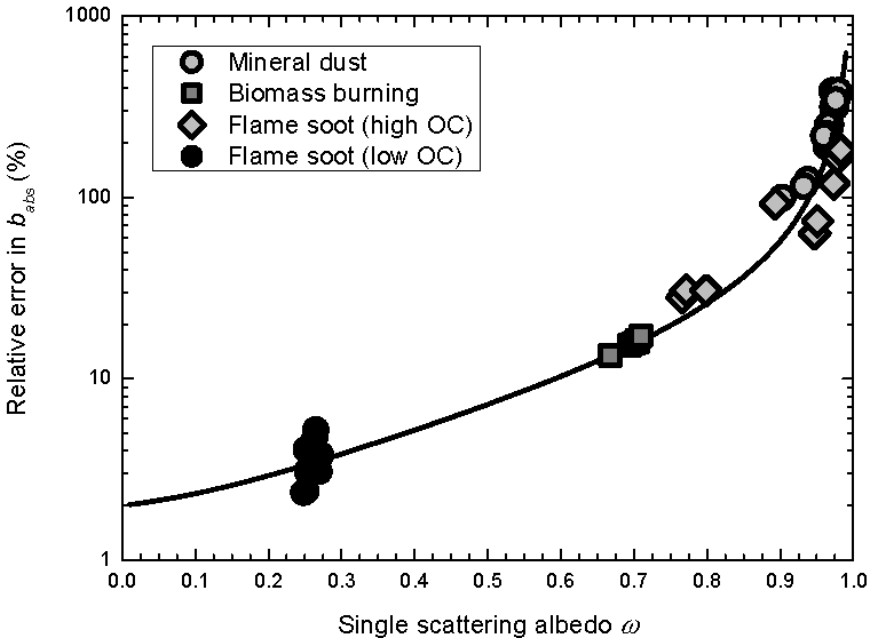
Elastic scattering: Reflection, Refraction, Diffraction
Inelastic scattering: Fluorescence, Raman

Aerosol Single Scattering Albedo



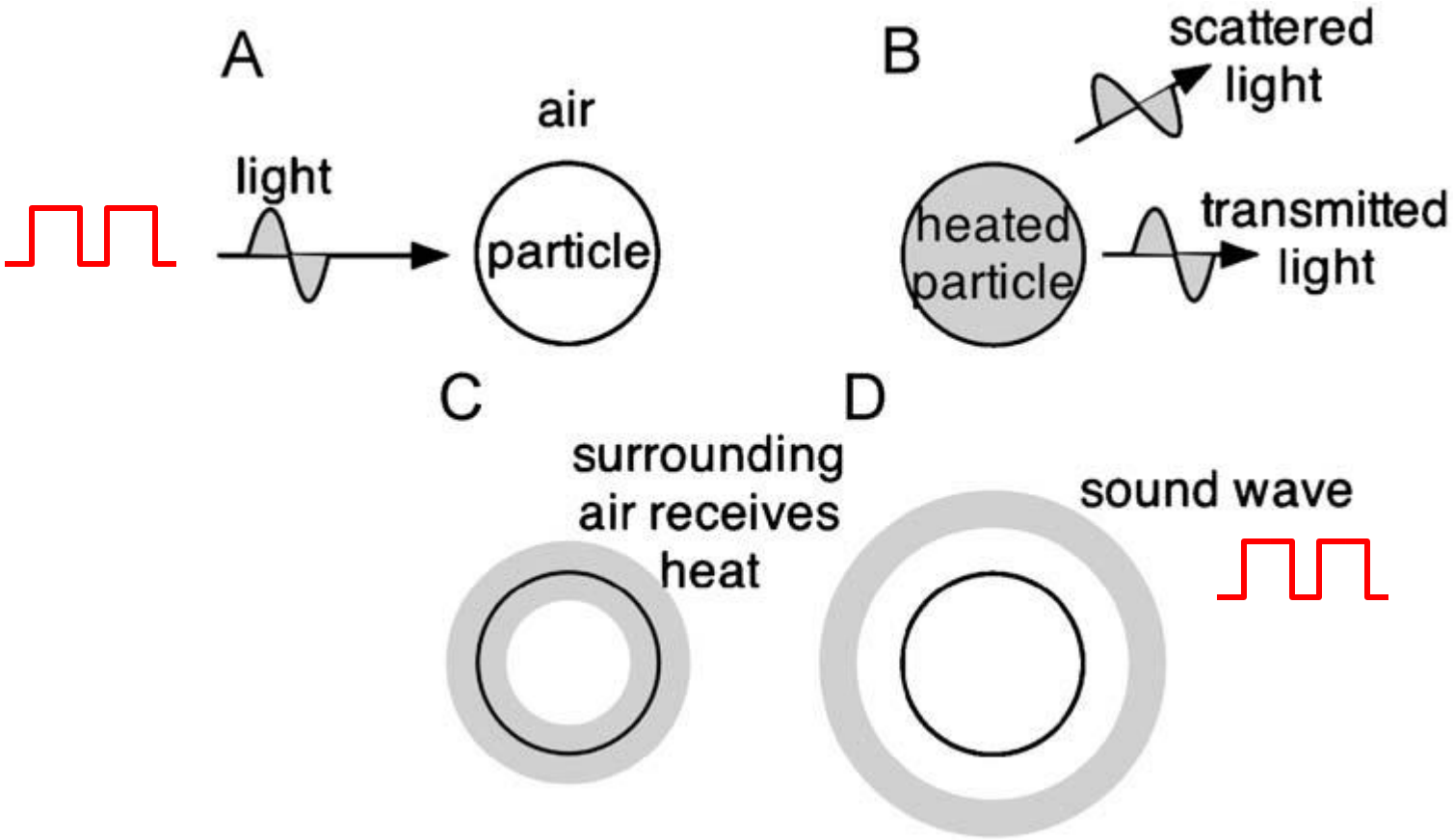
Hansen et al. (2000)

- Atmospheric aerosol has a high single scattering albedo $\frac{b_{sca}}{b_{ext}}$
- Difference measurements lead to high errors in b_{abs}

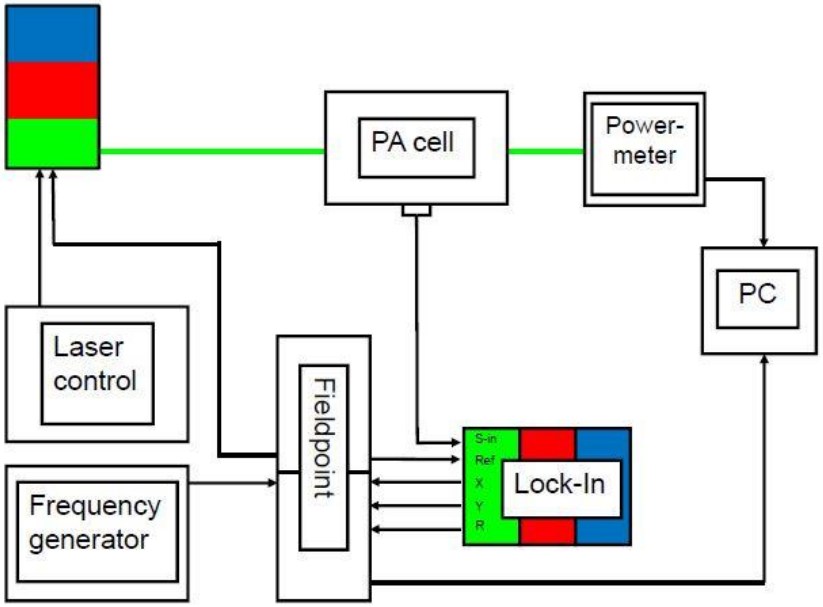


Ulanowski and Schnaiter (2011)

Photoacoustic Measurement Principle

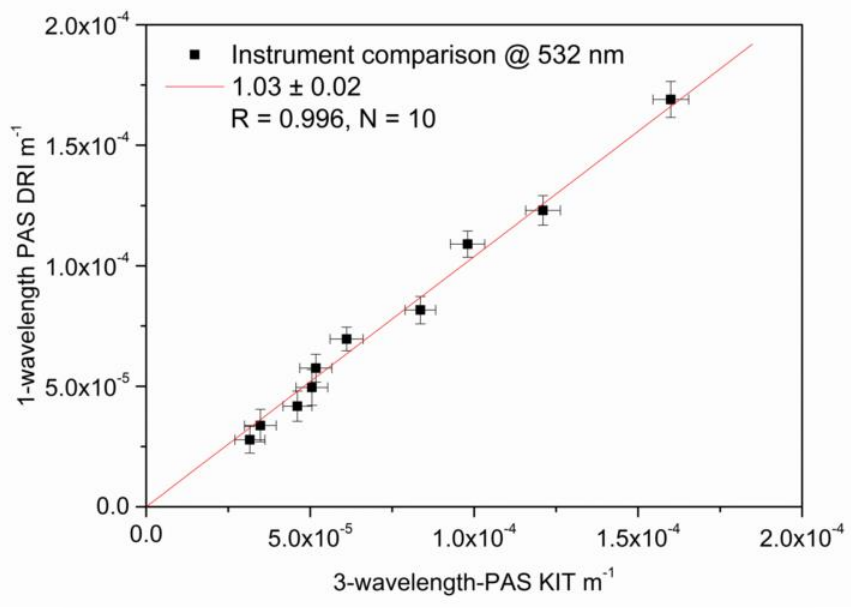


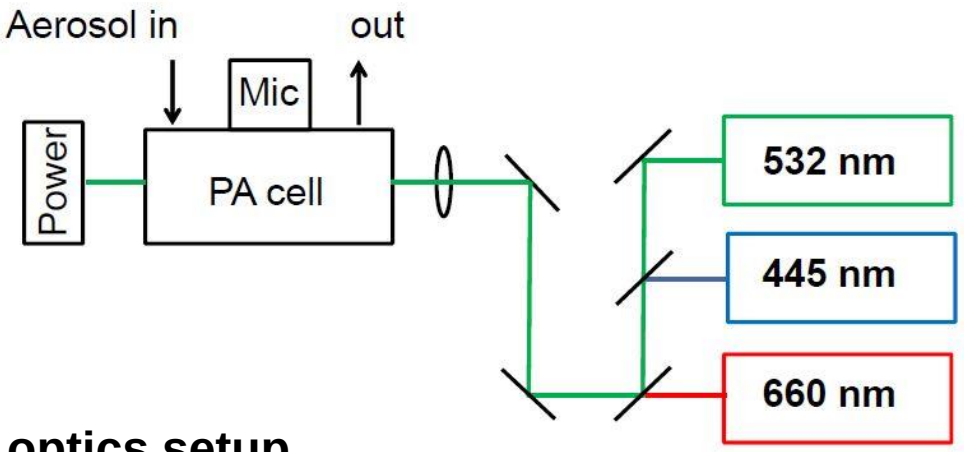
Single Cavity 3λ –Photoacoustic Instrument



electronics setup

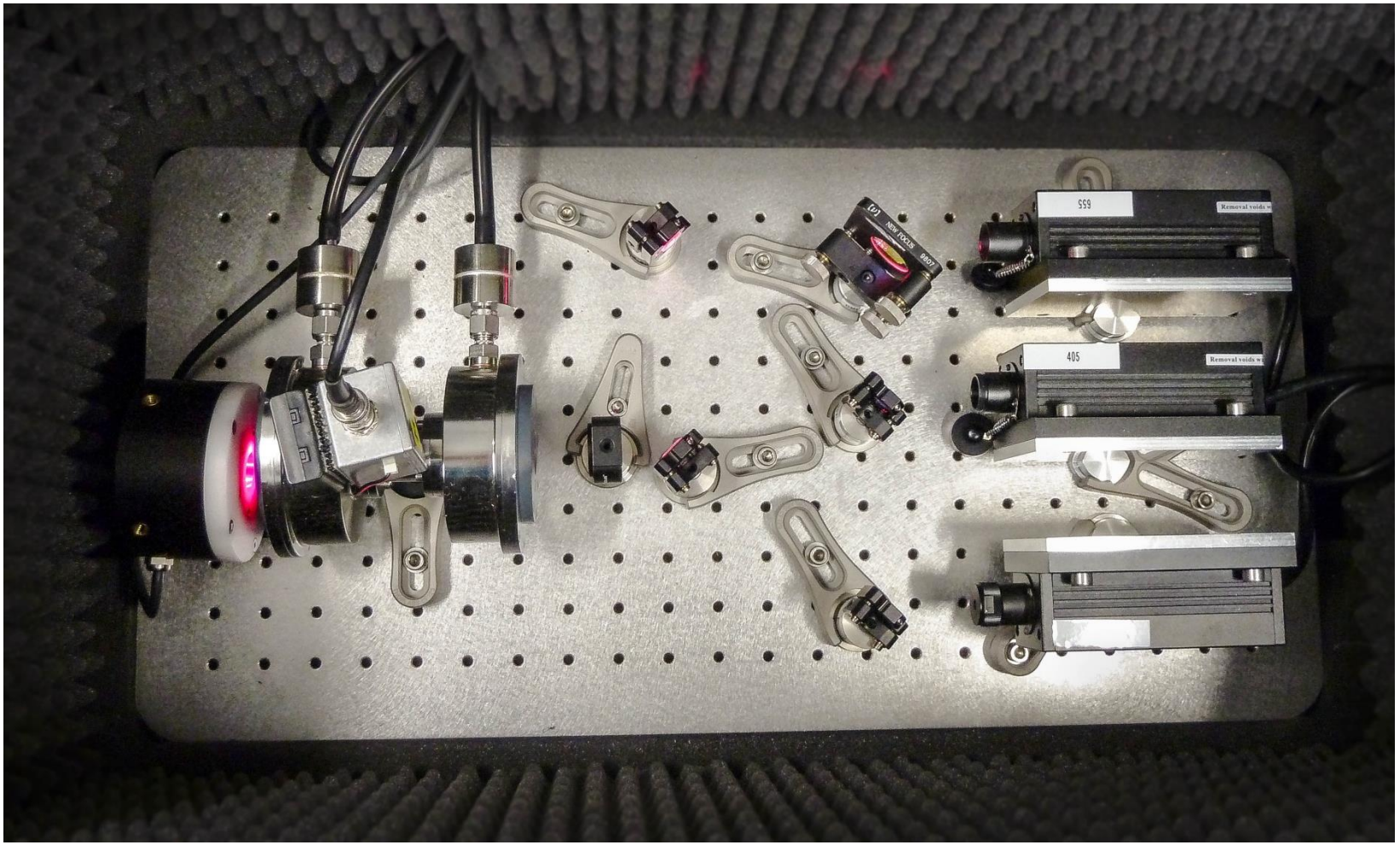
Detection limit: 5×10^{-6} to 1×10^{-5} 1/m





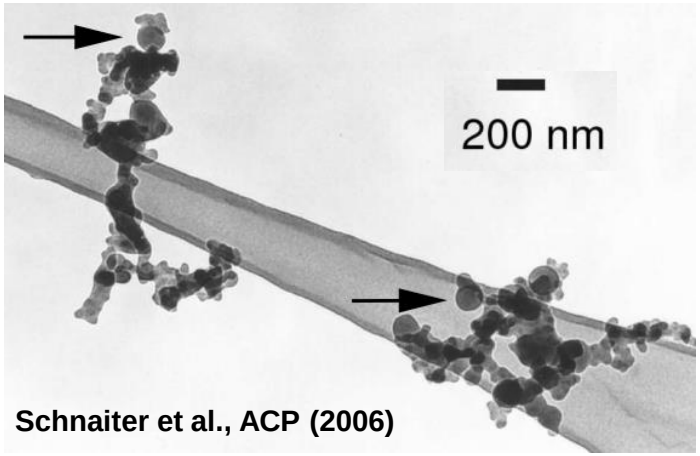
optics setup

Three Wavelength Photoacoustic Aerosol Spectrometer

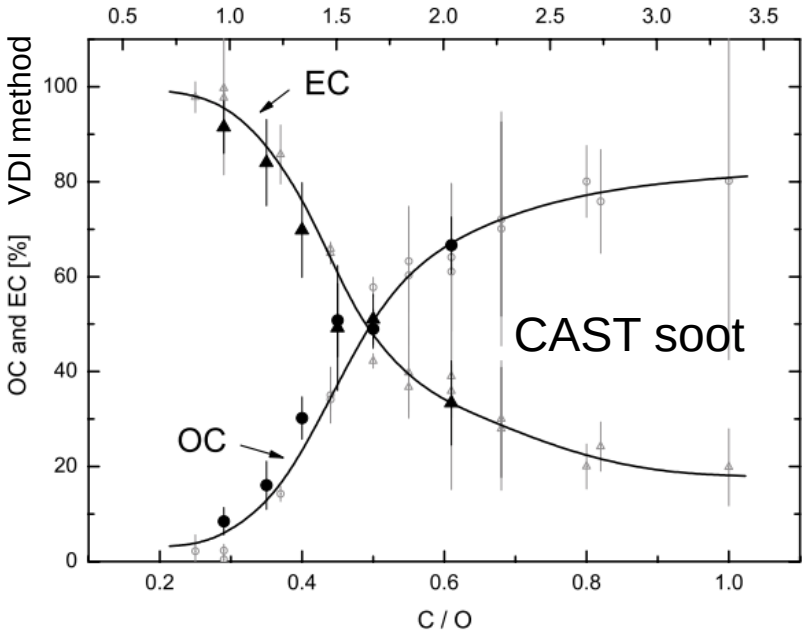


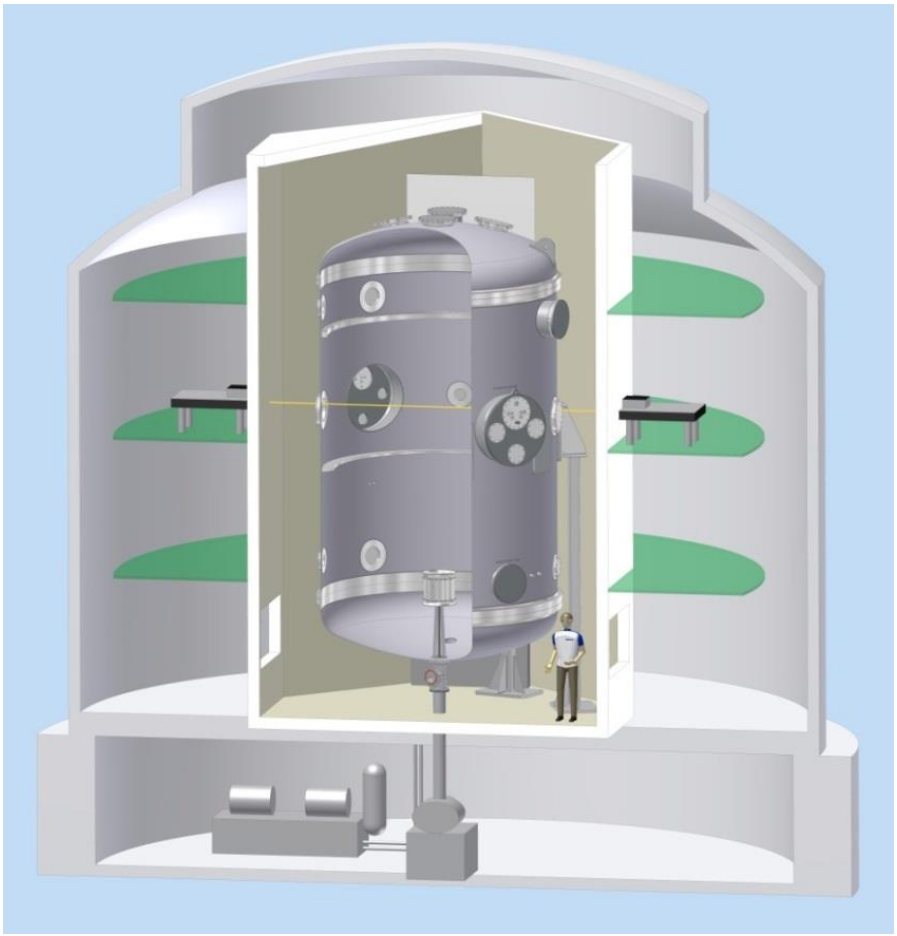
Institute of Meteorology and Climate Research
Atmospheric Aerosol Research

Aerosol Chamber Studies of Black Carbon



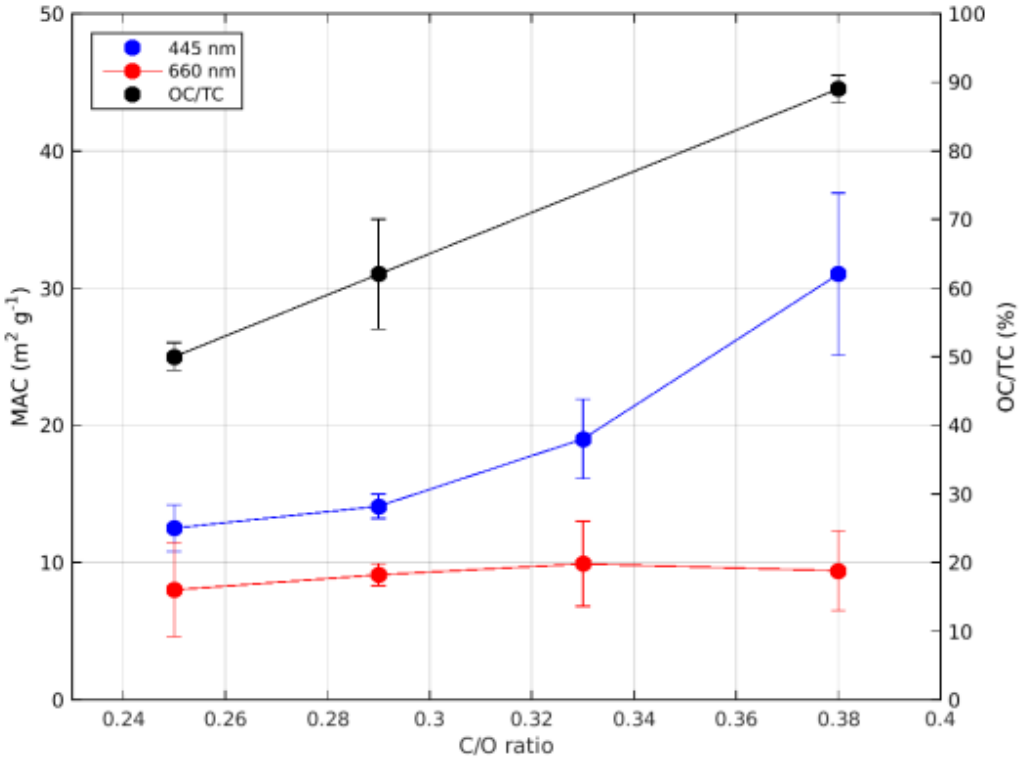
Schnaiter et al., ACP (2006)





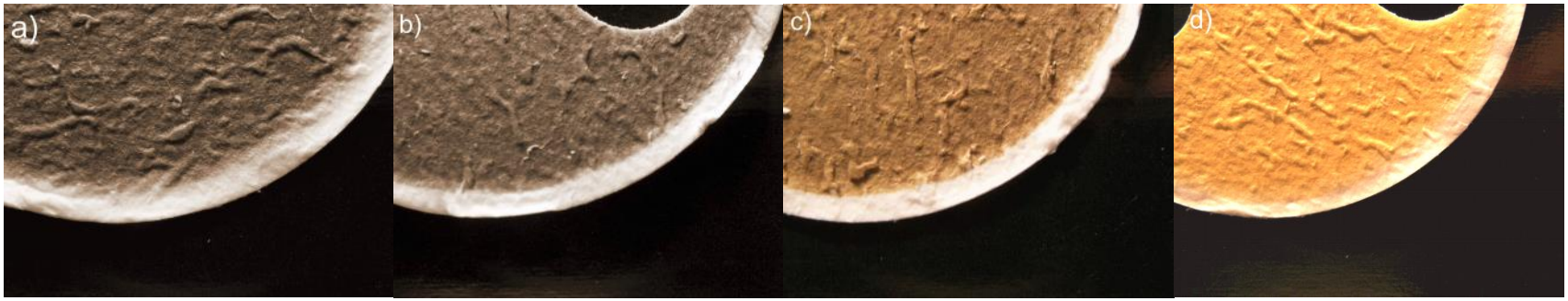
Institute of Meteorology and Climate Research
Atmospheric Aerosol Research

Spectral Dependence of Brown Carbon Absorption

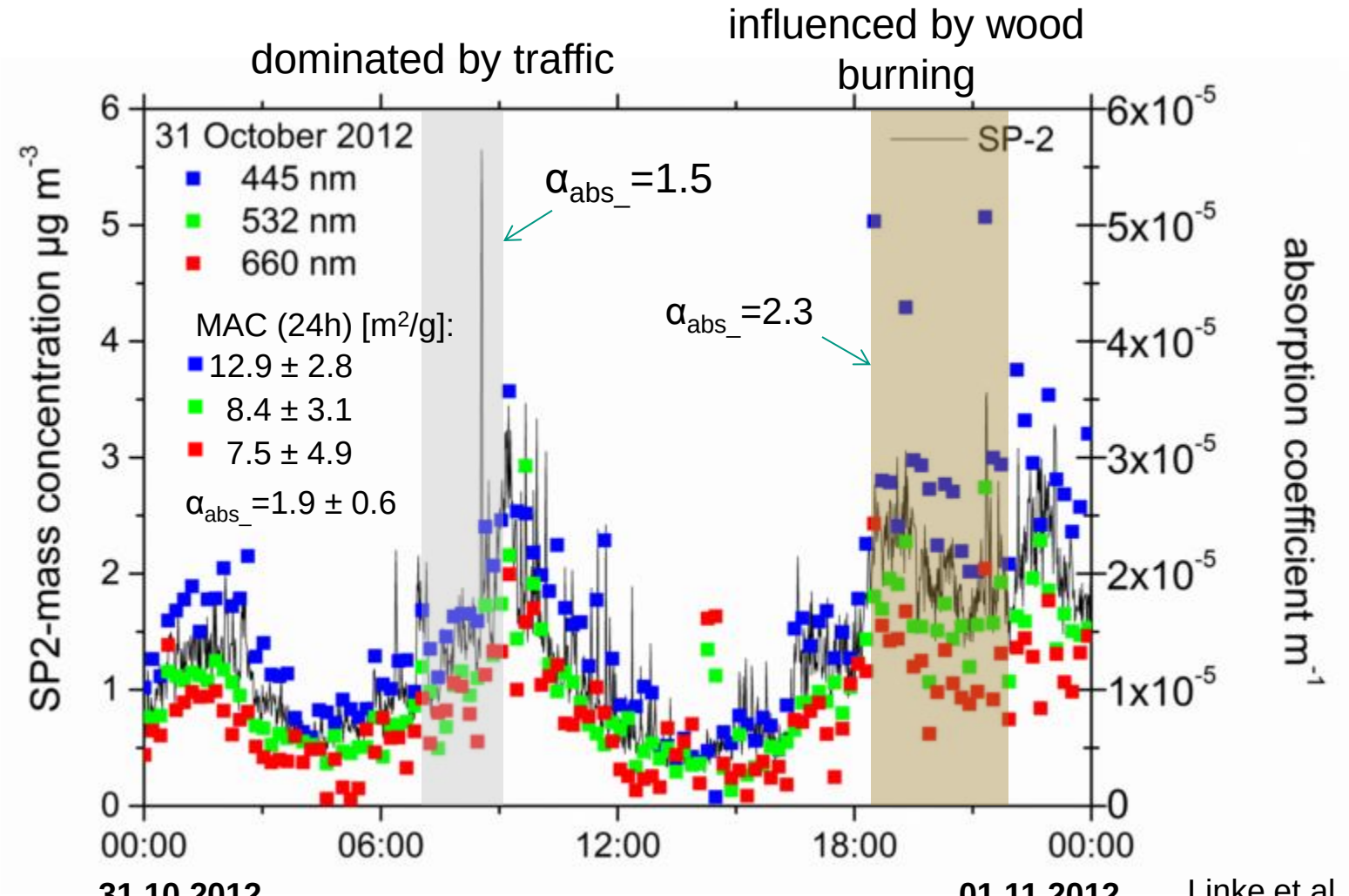


Ångström exponent of absorption

$\alpha_{abs\_}$=1.3 – 3.1



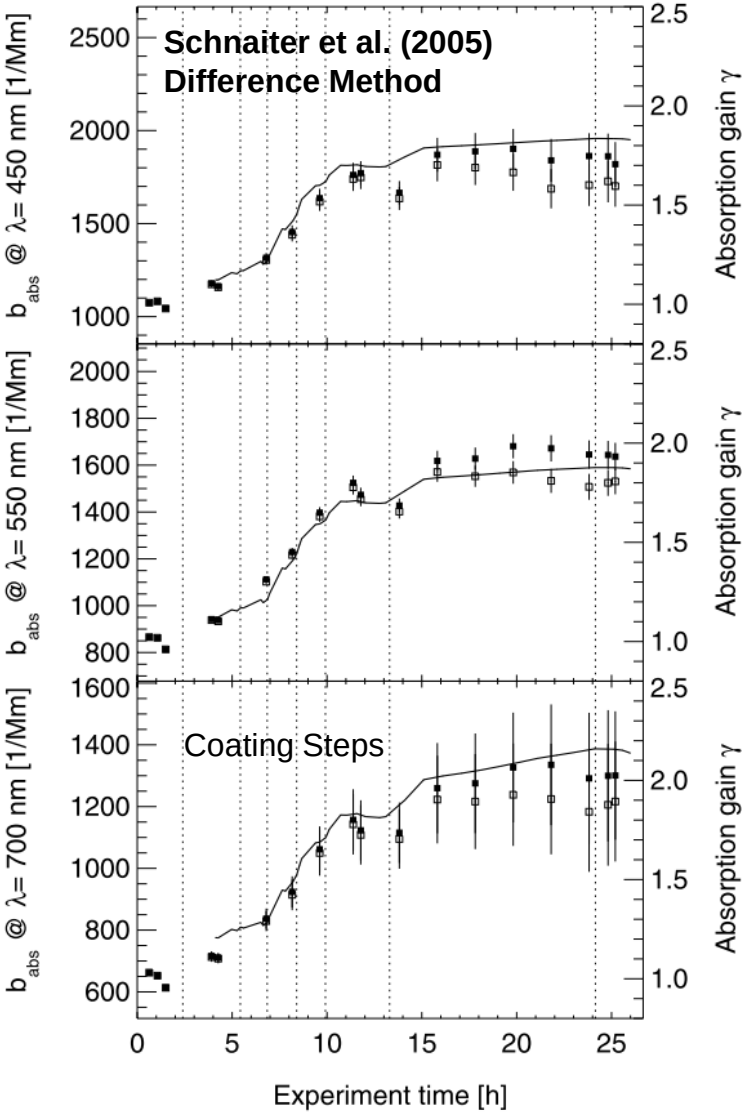
Field Study at an Urban Site

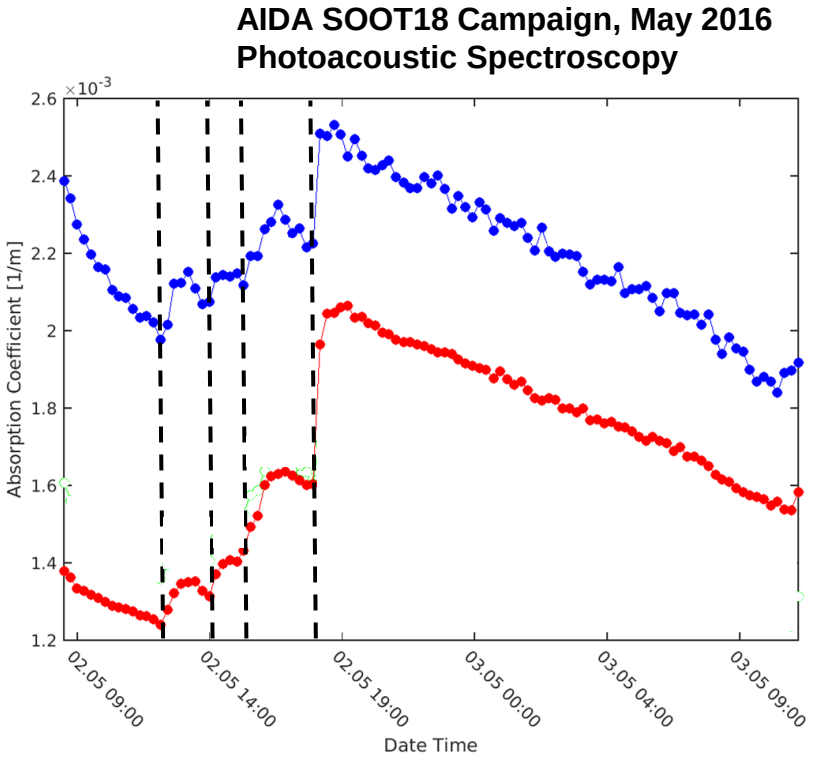


Linke et al. (2016)

Institute of Meteorology and Climate Research
Atmospheric Aerosol Research

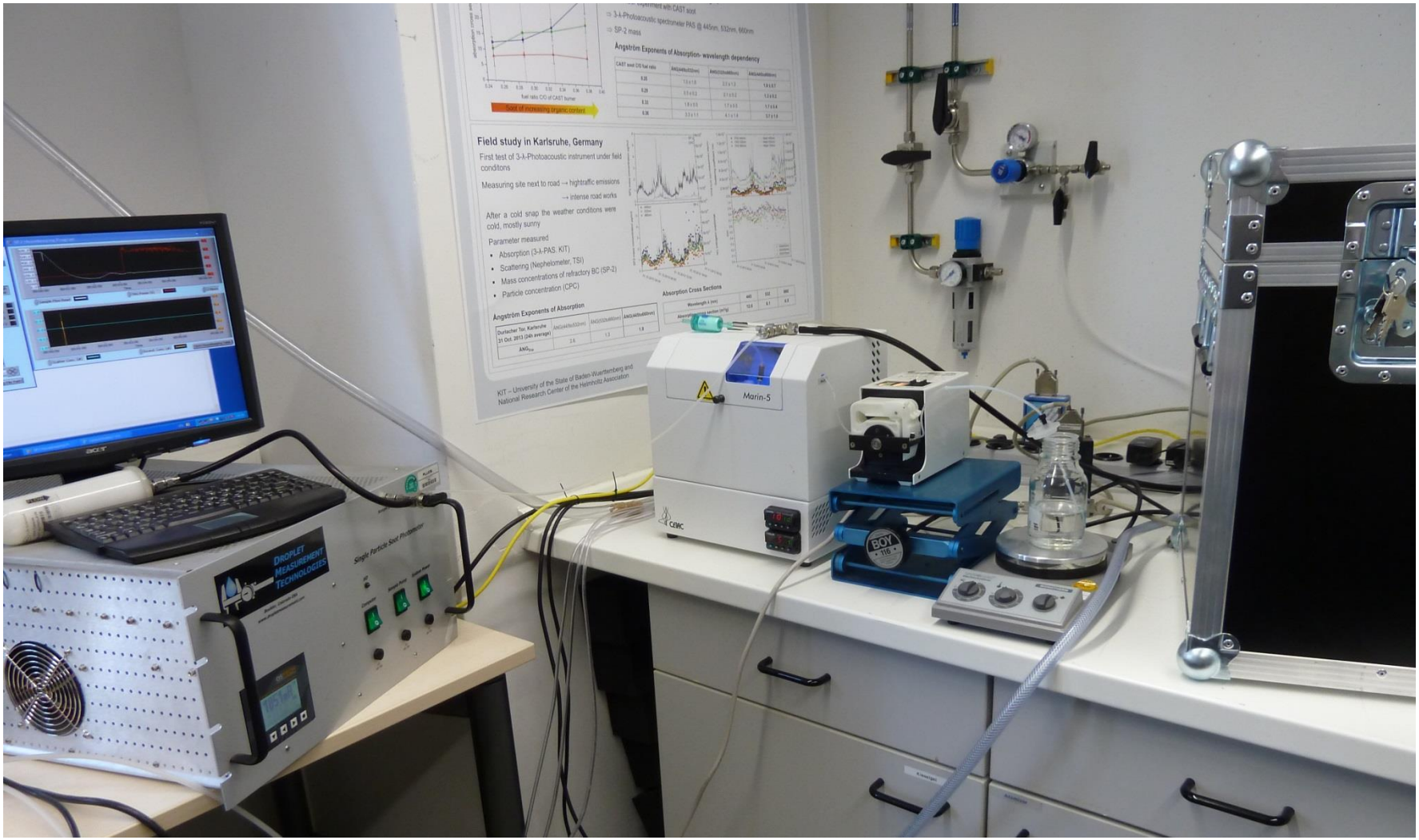
Soot Absorption Enhancement by Coating

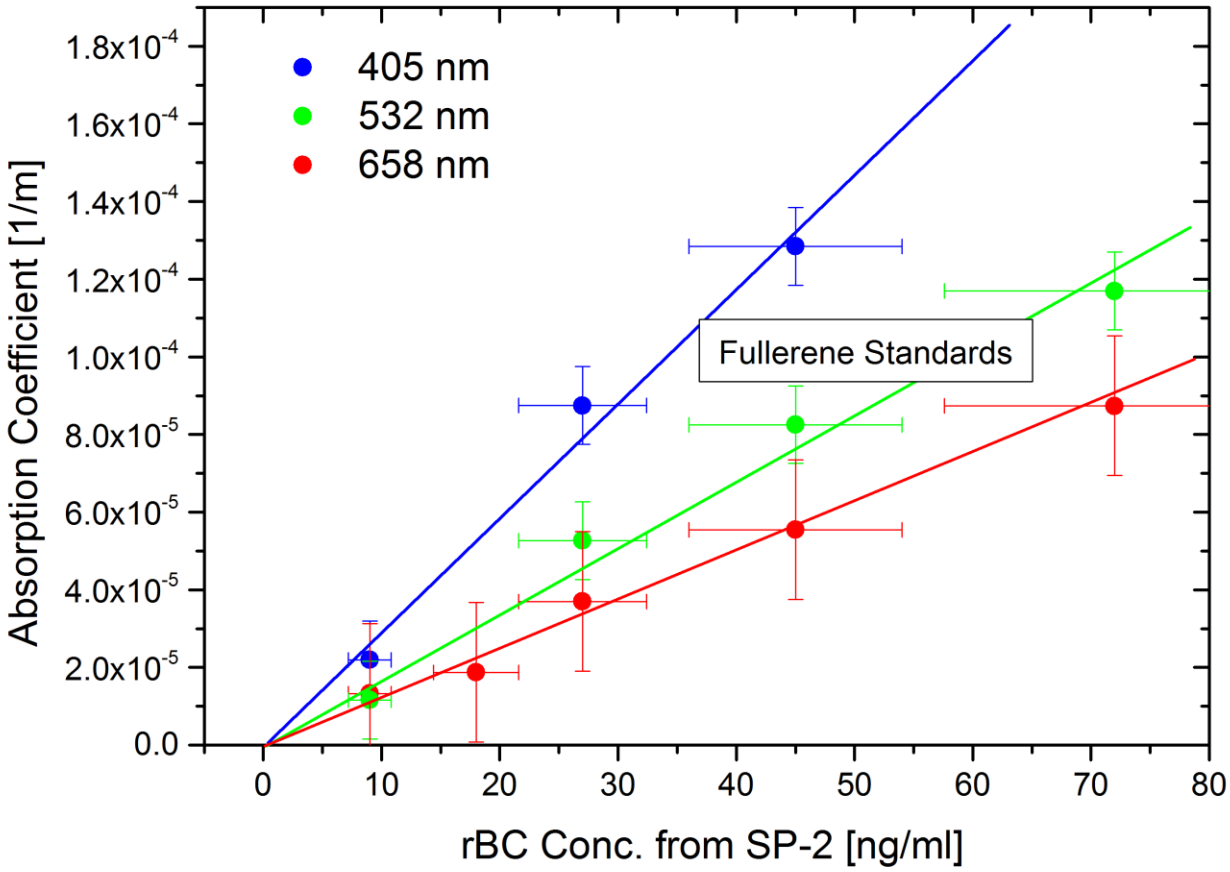




Institute of Meteorology and Climate Research
Atmospheric Aerosol Research

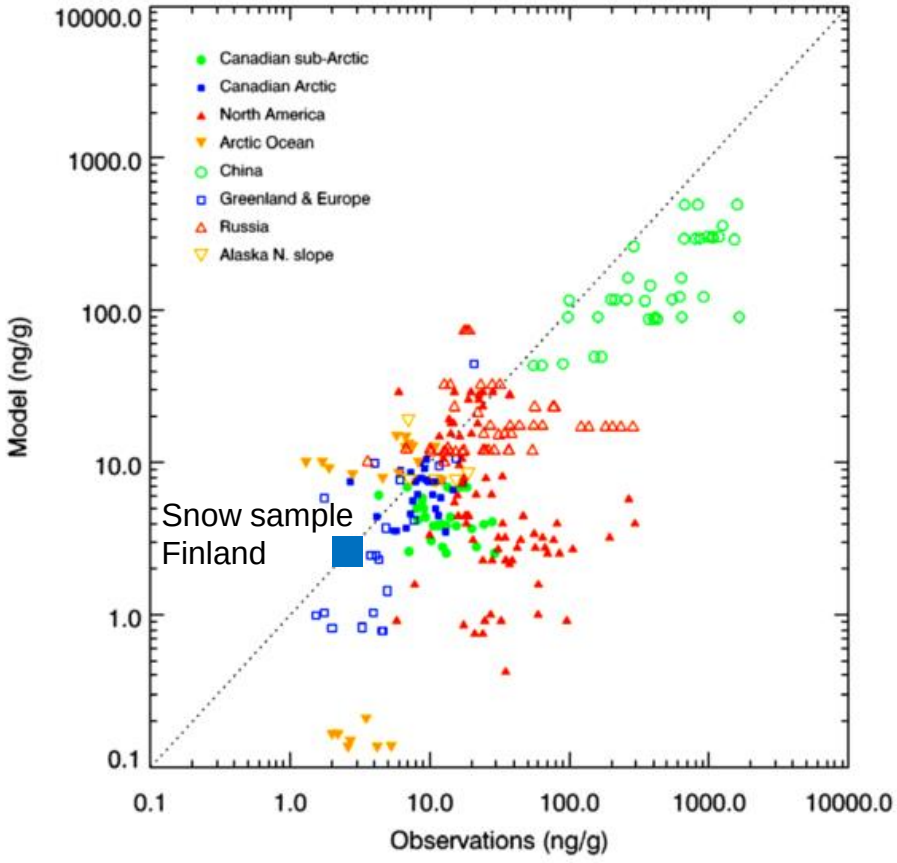
Photoacoustic and Black Carbon in Snow



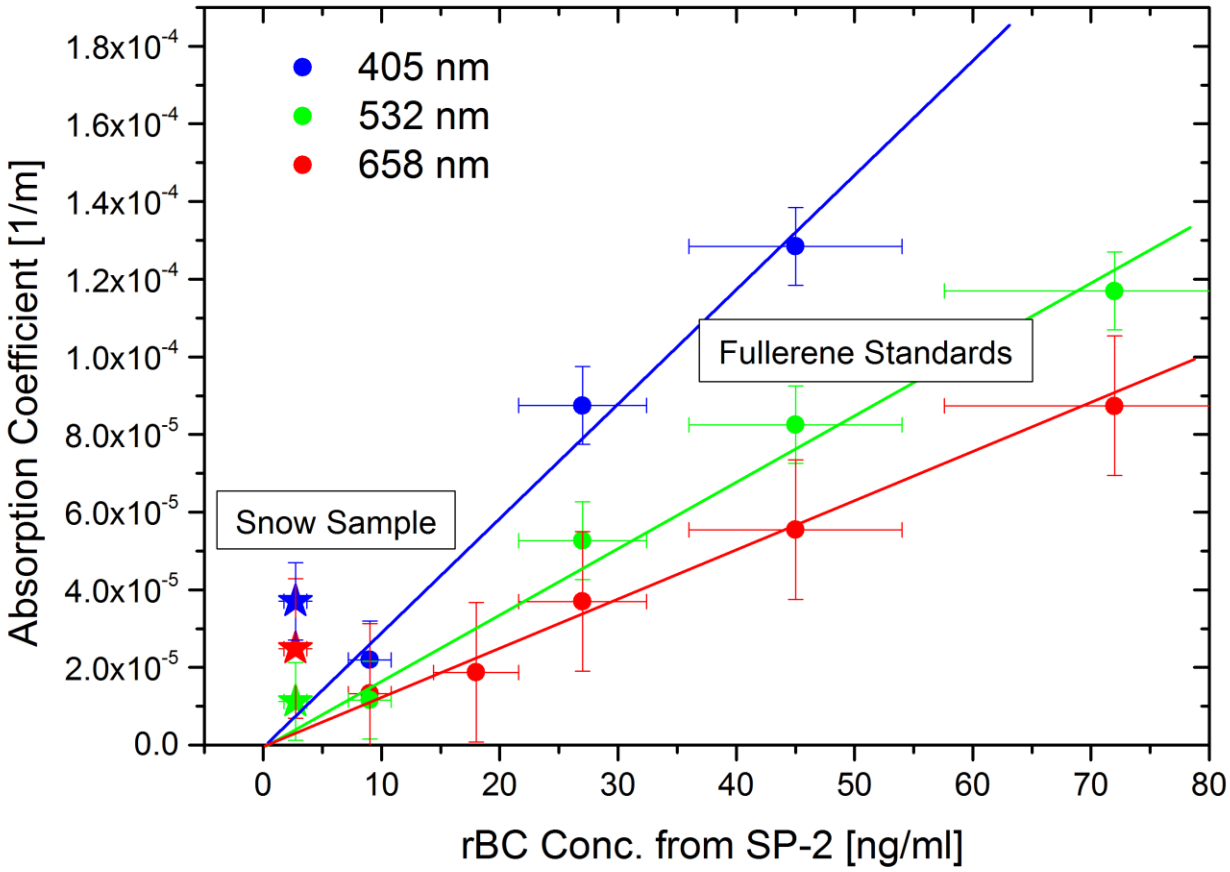


Institute of Meteorology and Climate Research
Atmospheric Aerosol Research

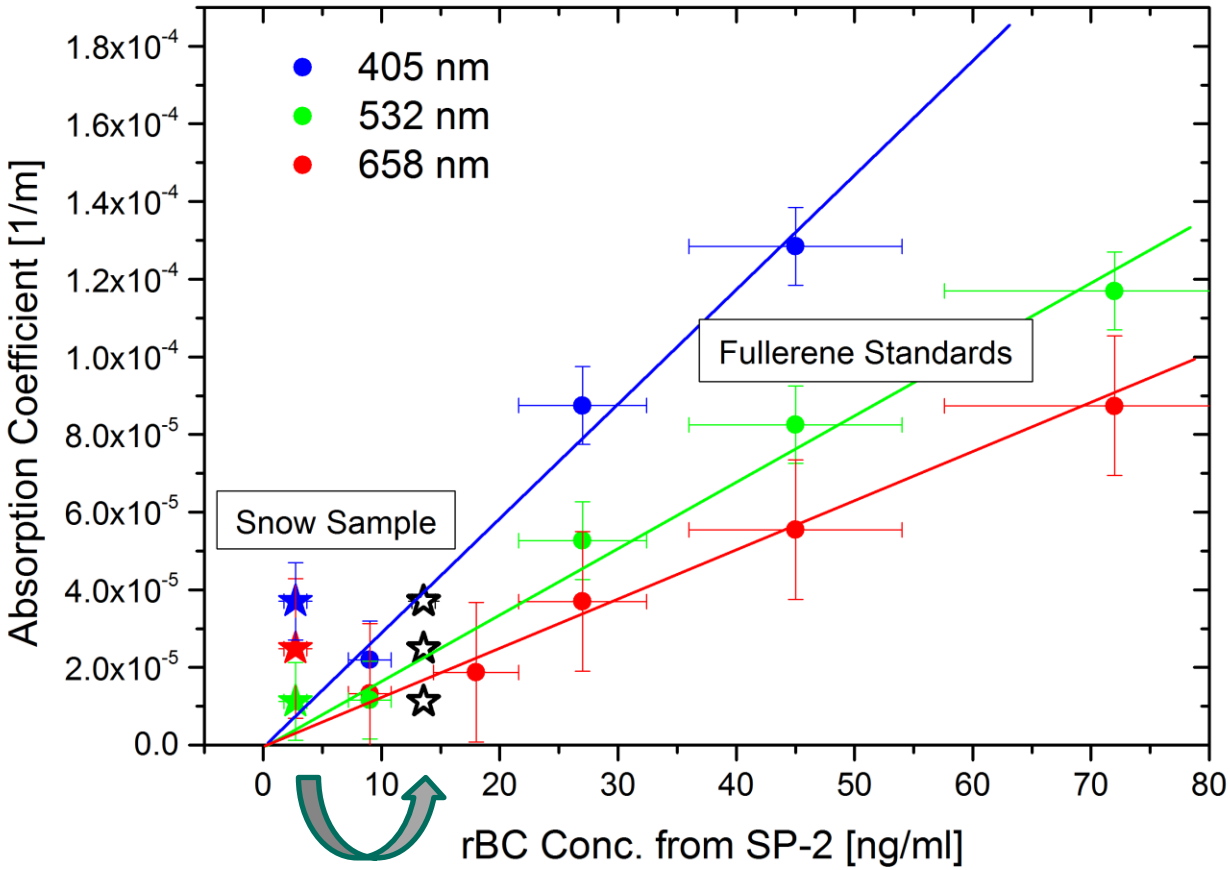
Snow Sample from Finland



Institute of Meteorology and Climate Research
Atmospheric Aerosol Research



Institute of Meteorology and Climate Research
Atmospheric Aerosol Research



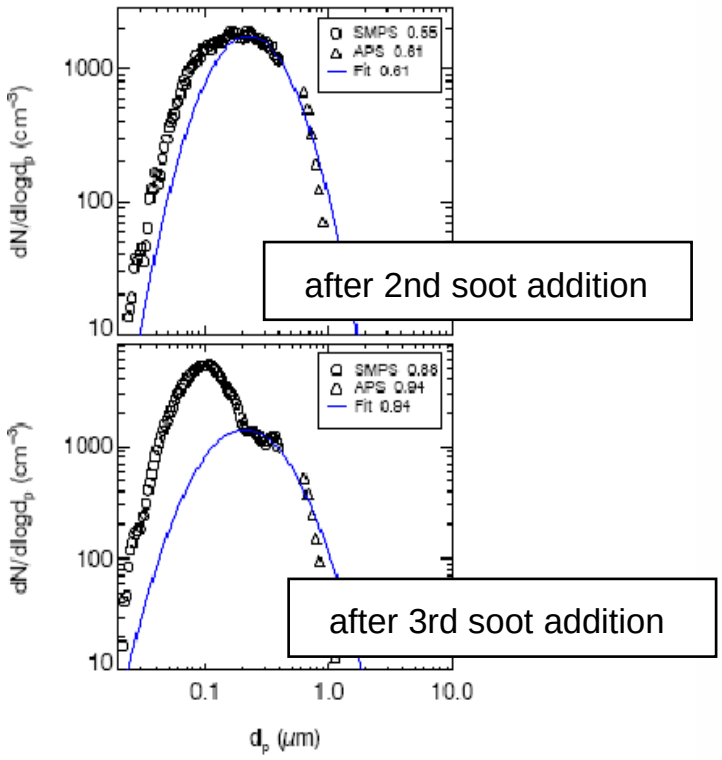
Apparent BC conc. from absorption

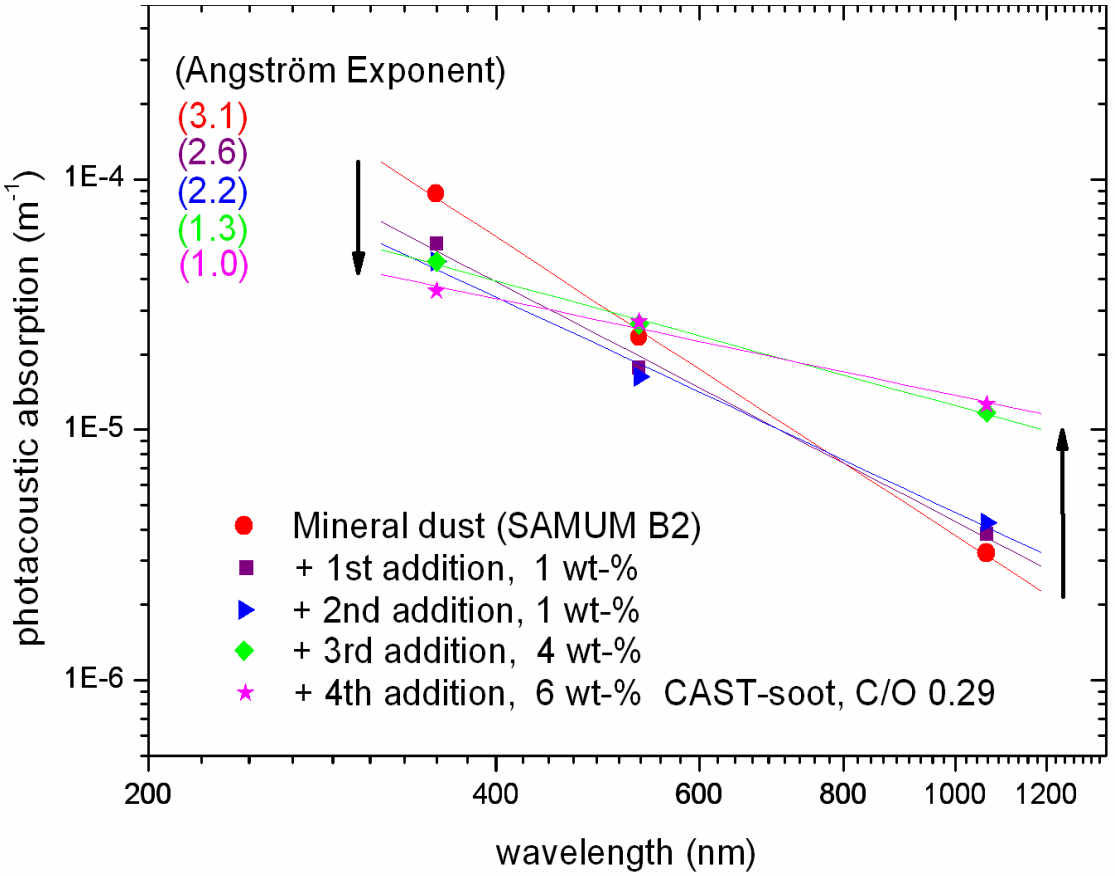
Institute of Meteorology and Climate Research
Atmospheric Aerosol Research

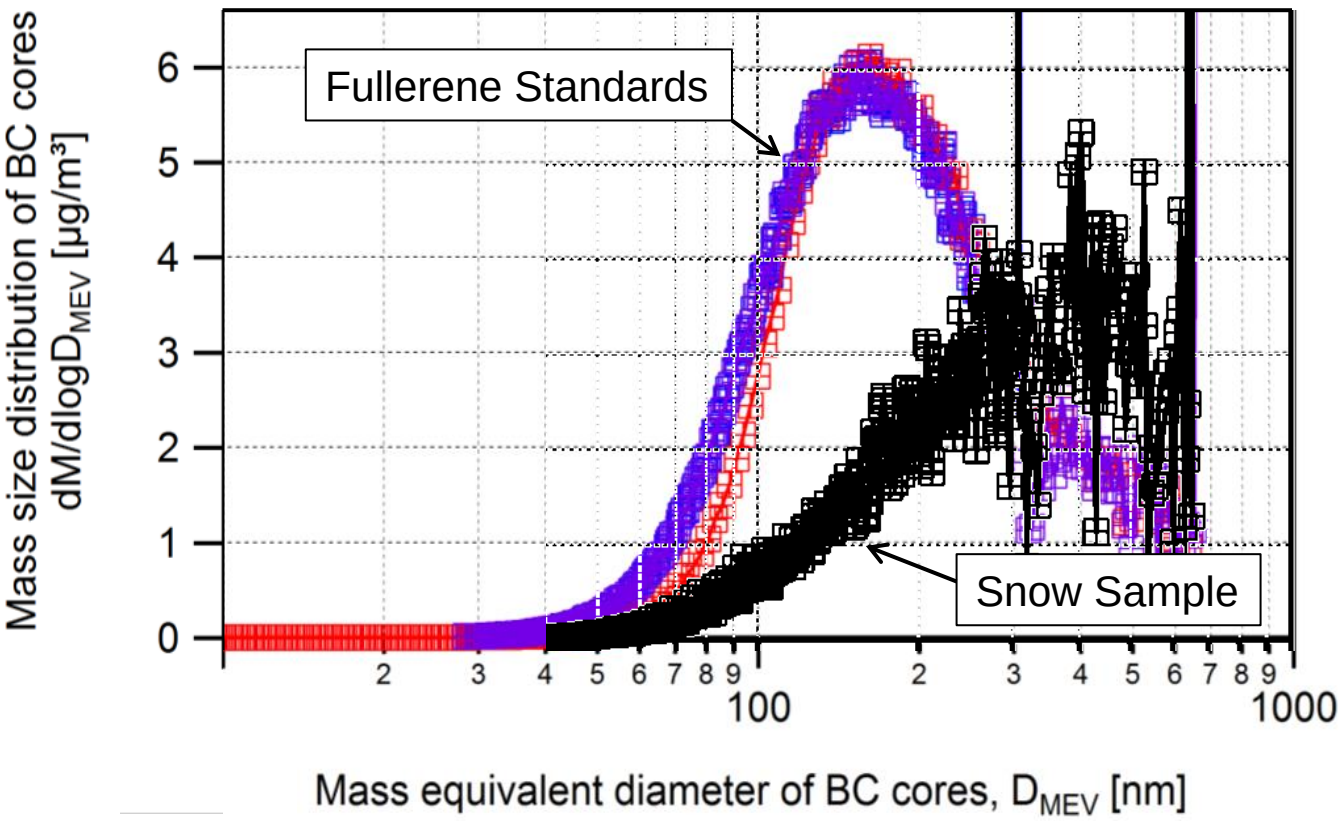
Future Activity Ideas

- Including multi-wavelength photoacoustics to urban and rural measurement stations
- Deploying the photoacoustic instrument to laboratory (chamber) studies on biomass burning emissions and black carbon aging
- Collaborating with research groups interested in the spectral absorption properties of aerosols in snow and ice packs (e.g. ice samples from glaciers)

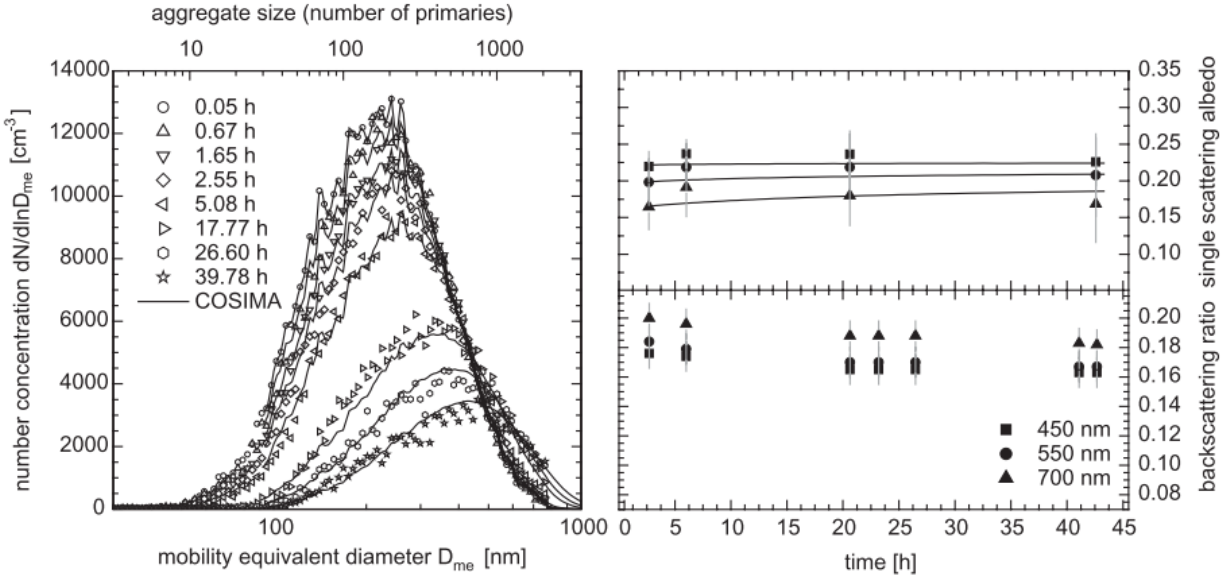
Black Carbon Mixed with Mineral Dust

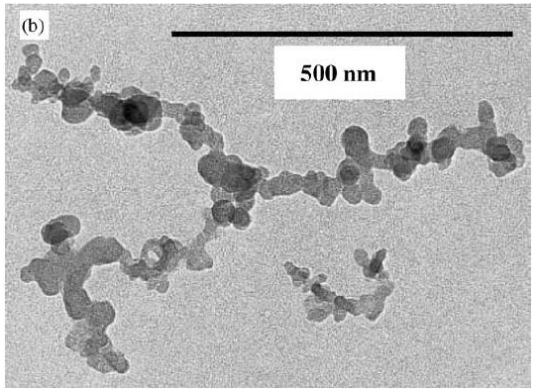





Fullerene Standards
Snow Sample
Mass size distribution of BC cores
dM/dlogD$_{MEV}$ [µg/m³]
Mass equivalent diameter of BC cores, D$_{MEV}$ [nm]
0
1
2
3
4
5
6
100
1000

Long Term Coagulation Experiment





COSIMA: Simulating the Aerosol Dynamics of Fractal Like Particles

https://www.imk-aaf.kit.edu/cosima_home.php

m(450 nm)=1.41 + i 0.64
m(550 nm)=1.49 + i 0.67
m(700 nm)=1.57 + i 0.73

Schnaiter et al. (2003)

$$\sigma_a^p = \frac{6\pi}{\lambda\rho}\,\mathrm{Im}\left\{\frac{m^2-1}{m^2+2}\right\}$$

$$\sigma_s = \sigma_s^p k_f \left(\frac{3D_f}{16x_p^2}\right)^{D_f/2}$$

$$\sigma_s^p = \frac{4\pi x_p^3}{\lambda\rho}\left|\frac{m^2-1}{m^2+2}\right|^2$$

Institute of Meteorology and Climate Research
Atmospheric Aerosol Research