Calibration experiments for filter based absorption photometers during the EUSAAR-2009 photometer workshop

Müller, T.[1], Henzing, J.S.[2], Sheridan, P.J.[3], Wiedensohler, A.[1], Virkkula, A.[4], Mocnik, G.[5], Walker, J.[6], Fialho, P.[7], Eleftheriadis, K.[8], Filep, A.[9], de Leeuw, G.[2,4,10]

[1]Leibniz Institute for Tropospheric Research, Leipzig, Germany

[2]TNO, Utrecht, The Netherlands, [3]NOAA Earth System Research Laboratory, Boulder, USA

[4]University of Helsinki, Helsinki, Finland, [5]Aerosol d.o.o., Ljubljana, Slovenia

[6]Droplet Measurement Technologies, Boulder, USA, [7]University of Azores, Terra Cha, Portugal

[8]E.R.L., Institute of Nuclear Technology - Radiation Protection, NCSR "Demokritos", Athens, Greece

[9]University of Szeged, Szeged, Hungary, [10]Finnish Meteorological Institute (FMI), Helsinki, Finland

ift tropospheric aerosols

EUSAAR

Intention of the Absorption Photometer Workshop

- At many EUSSAAR sites particle absorption is measured by filter based absorption photometers, which measure the light transmittance while loading a filter (PSAP and Aethalometer)
- These filter based absorption photometers
  - …have a loading effect ⇒ the sensitivity of instruments changes with the mass of collected particles.
  - …have a cross sensitivity to particle scattering ⇒ particle scattering misleadingly can be interpreted as particle absorption.
- There exist different schemes to correct for loading and scattering effects:
  - Aethalometer: Weingartner et al. (2003), Arnott et al. (2005), Schmid et al. (2006), Collaud Coen et al. (2010)
  - PSAP: Bond et al. (1999), Virkkula et al. (2005)

➢ **Develop a correction scheme which can be applied to PSAP and Aethalometer data, to make measurements done with these instruments more comparable.**

Principle of operation of filer based absorption photometers

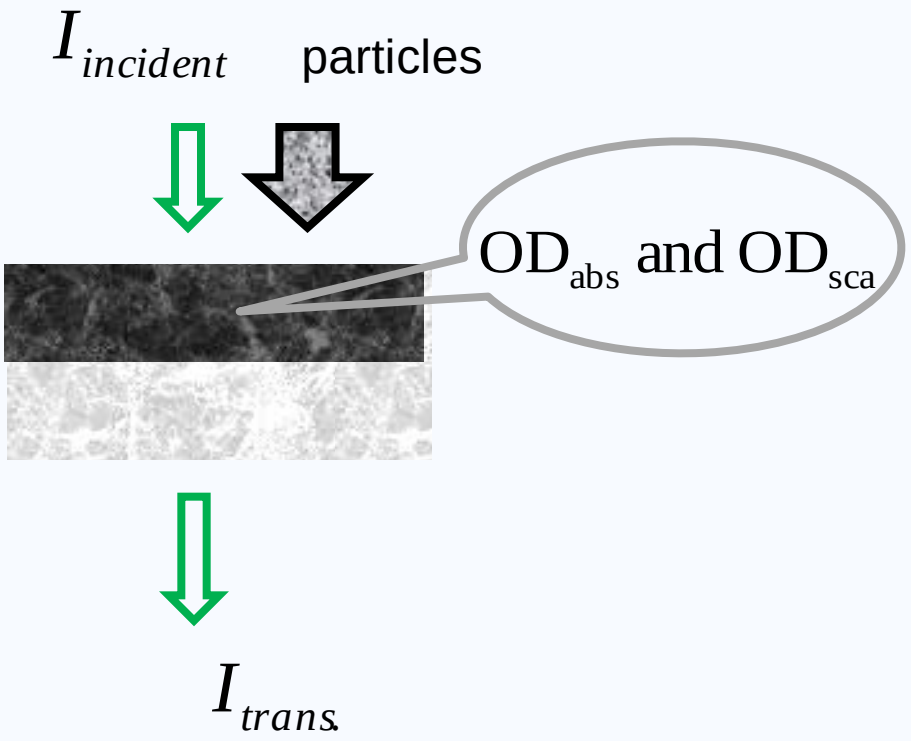
1. Collecting particles in the uppermost part of a fiber filter

2. Measuring optical attenuation ATN

$$ATN = -\ln\left(\frac{I_{trans}(L)}{I_{trans}(L=0)}\right)$$

where L is the length of the column of air sucked through the filter in a certain time

3. ATN is *related* to the absorption and scattering optical depths OD_{abs} and OD_{sca}



existing corrections schemes

$$ATN = -\ln\left(\frac{I}{I_t}\right.$$

suring optical
tenuation

loss of information

$$\sigma_{sca} = \frac{d}{dL} OD_{sca}$$

$$\sigma_{ATN} = \frac{d}{dL} ATN$$

ation
coefficient:
1st derivative w.r.
to length

$$\sigma_{abs} = f(\sigma_{ATN}, \sigma_{sca}, ATN)$$

applying scattering
and loading
correction

new correction scheme

- **full information on loading state**
- **can be solved by <u>radiative transfer calculations</u>**

Radiative transfer model

Radiative transfer model (RTM) for particles embedded in a filter matrix is given in Literature (e.g. Arnott et al., 2005)

$$ATN = \mathrm{RTM}\left(OD_{abs}, OD_{sca}, g_{sca}\right)$$

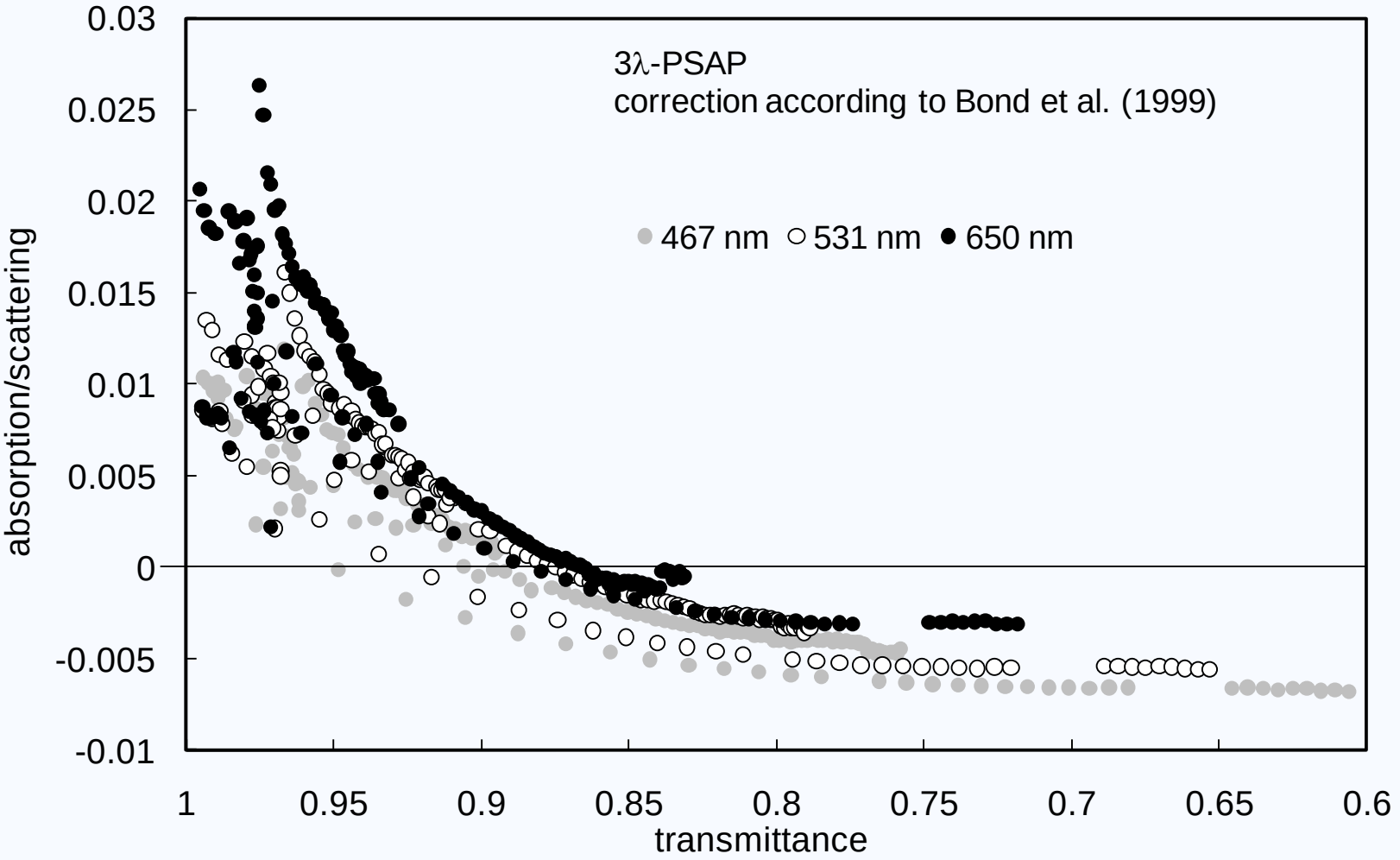
measured by photometer

absorption "target property"

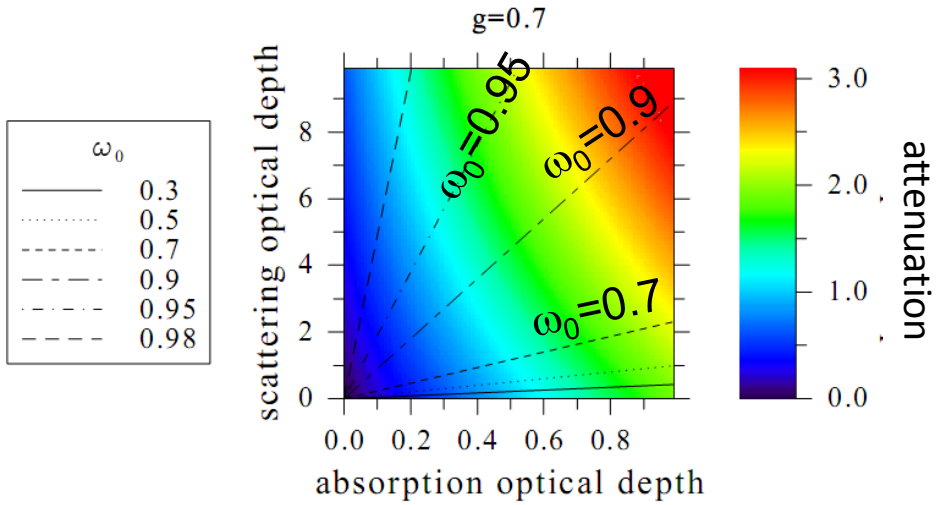
measured by total - backscattering nephelometer

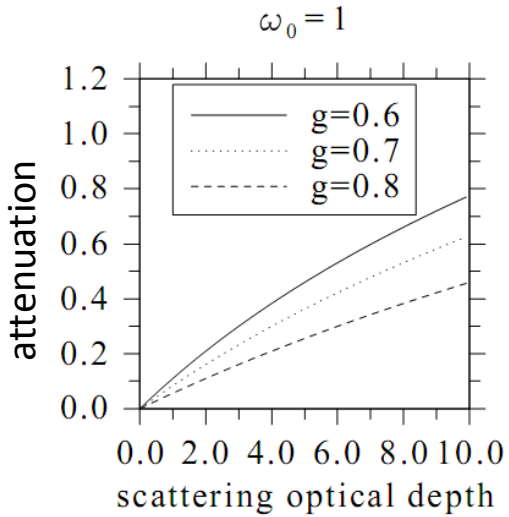
- ATN depends on the particle asymmetry parameter g_{sca} !
- Asymmetry parameter depends on refractive index, particle size, and wavelength.
- Dependence on asymmetry parameter is not considered in any of the older correction schemes !

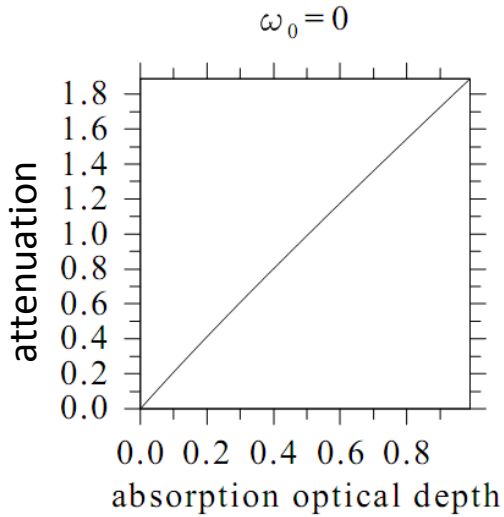
EUSAAR-2007 absorption photometer workshop



Simulation of attenuation of PSAP using RTM







Issues of the radiative transfer model:

- … considers limited number of layers
- … does not consider interference effects of particles and fibers. Although particles are sticking on the surface of fibers, absorption and scattering cross sections are assumed to be still the same as for airborne particles.

- It is not possible to quantify loading and scattering effects with models only.
- Model must be constrained to fit to experimental results.
- We need calibration experiments

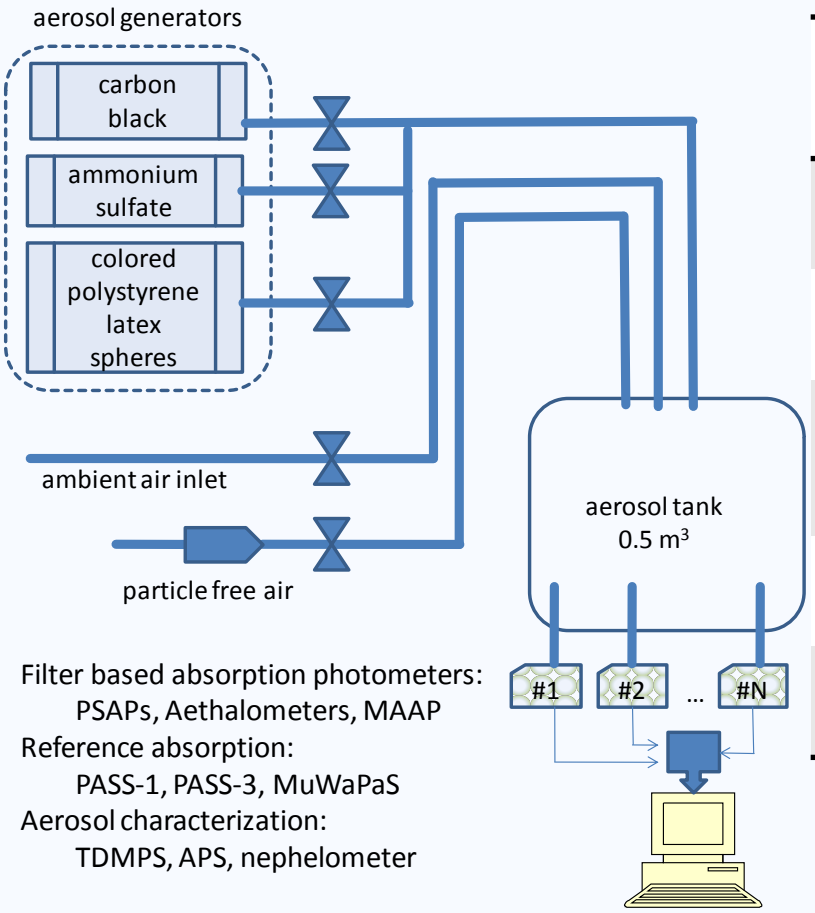
Instruments used during the EUSAAR-2009 calibration workshop

- All instruments were checked
- A subset of instruments was selected for calibration experiments

	instrument	model	# instr.	# instr. used for calibration experiments
Absorption measurements	Aethalometer	7-λ AE31	8	4
	Aethalometer	2-λ AE9	1	
	PSAP	3-λ	4	3
	PSAP	1-λ	2	1
	MAAP			
	SOAP			
	MuWaPaS	4-λ	1	1
	PASS-3	3-λ	1	1
	PASS-1	1-λ	1	1
Scattering measurements	Nephelometer	TSI model 3563	3	1
	Nephelometer	Ecotech model 9003	1	

Reference for absorption and scattering optical depths

Experimental setup



Filter based absorption photometers:
PSAPs, Aethalometers, MAAP
Reference absorption:
PASS-1, PASS-3, MuWaPaS
Aerosol characterization:
TDMPS, APS, nephelometer

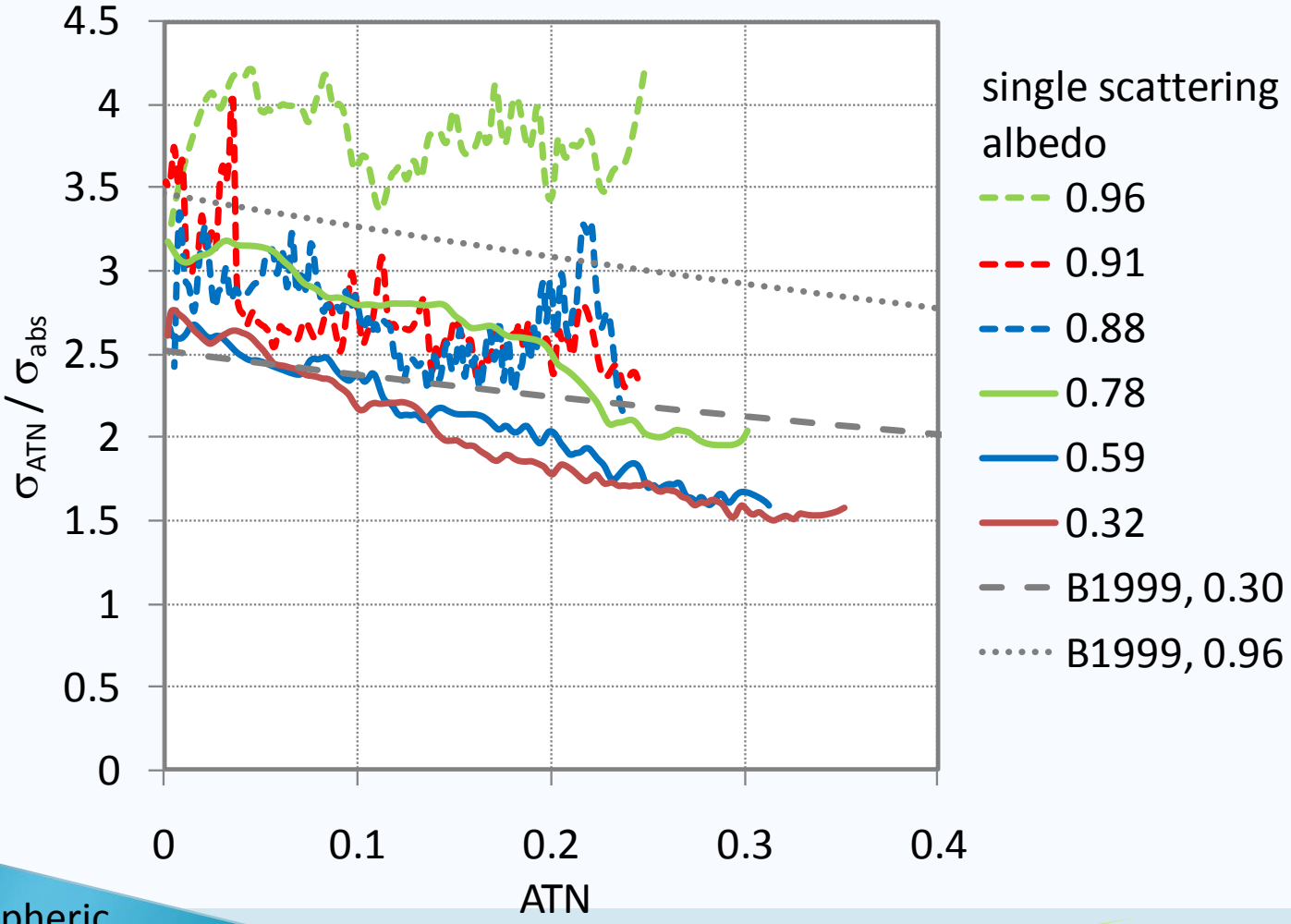
Aerosol type	Ångström exponent(1)	Single scattering albedo(2)
Black (Printex 75, P75)	0.89	0.32
White (ammonium sulfate, AS)	0.08 to 2.5	0.997-0.999
Gray (external mixture of P75 and AS)	1.22 to 1.41	0.59 to 0.96
Colored (colored PSL spheres)	-1.31 to 1.98	0.71 to 0.81
Ambient	1.97 to 2.3	0.78 to 0.83

(1)Ångström exponents were derived from PASS-3 at wavelengths 405 and 532 nm
(2)Single scattering albedos were determined with PASS-3 and a nephelometer at 532 nm.

Results

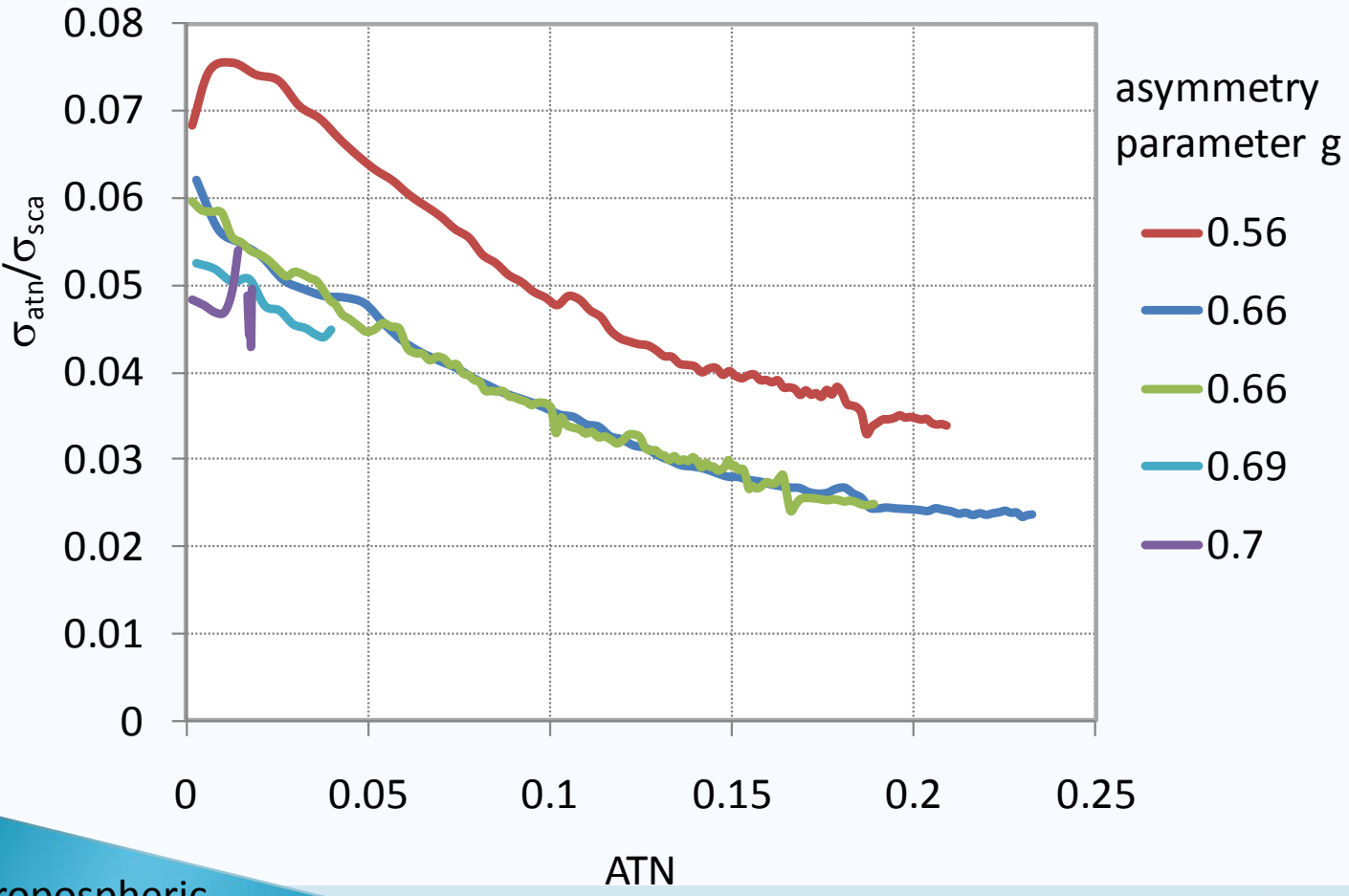
Experiments with black (ω_0=0.3) and gray particles (0.59<ω_0<0.96)

Instrument: PSAP, wavelength 532 nm

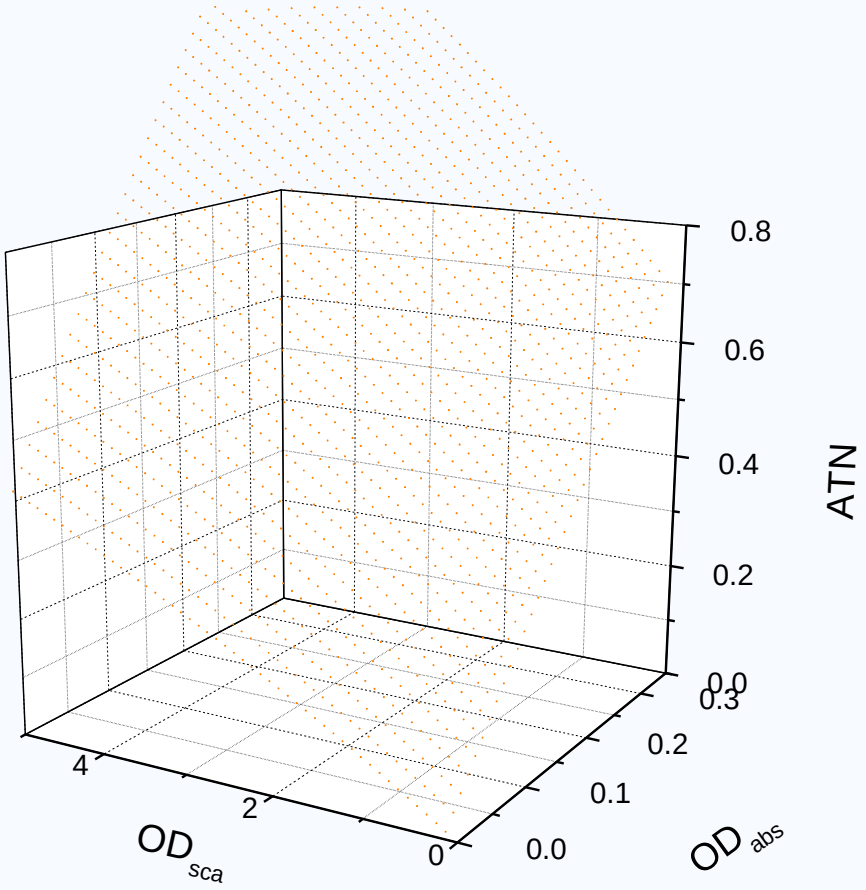


Experiments with white particles (single scattering albedo ω_0=1)

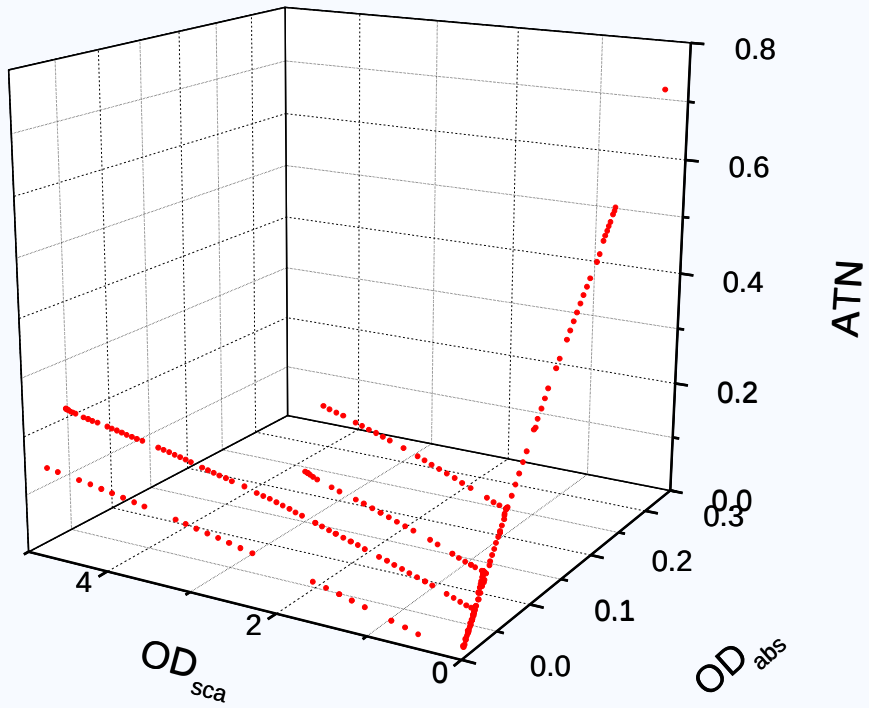
PSAP, λ= 532 nm



radiative transfer model



experiment



- At low single scattering albedos the radiative transfer model fits well to measured data
- At high single scattering albedos the model overestimates the attenuation

Outlook

- Development of correction scheme
  - Constraining the model to fit to measured data for PSAP
  - Setup up radiative transfer model for Aethalometer and constrain it to fit to experimental results
- Since the radiative transfer model efforts many steps of data pre-prosessing a simplified method would be helpful.
  - e.g. parameterizations for constant single scattering albedos

Acknowledgements

The workshop was supported by ACCENT, EUSAAR, EUCAARI, and the WCCAP. The authors would like to acknowledge Droplet Measurement Technologies, Aerosol d.o.o. and Hilase Ltd. for supporting the workshop.