Development of reference instruments for multi-wavelength absorption measurements

Thomas Müller,
Leibniz Institute for Tropospheric Research, Leipzig

ACTRIS-2 WP3 Workshop Athens 10-12 November 2015

ACTRiS

Member of Leibniz Association

TROPOS
Leibniz Institute for Tropospheric Research

Introduction

The goal was to setup a reference instrument for measuring the light absorption coefficient of airborne particles

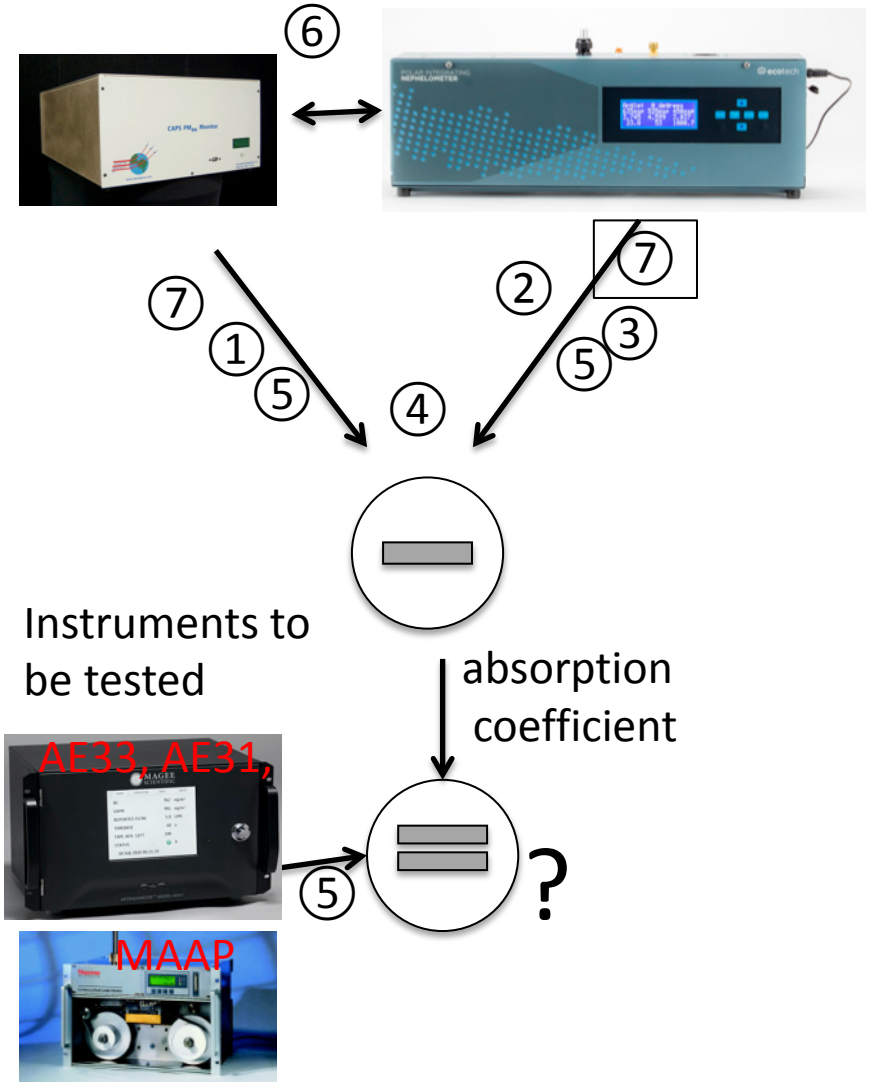
- Reference for Multi-Wavelength Absorption photometers
- Calibration of reference instrument should be linked to fundamental physical measurements (SI traceable)

The method of choice is "*extinction minus scattering*"

Reference setup consist of commercial available instruments

- One three wavelength Nephelometer (Aurora 4000) for measuring the scattering coefficient
- Three Cavity Attenuated Phase Shift (CAPS) monitors for measuring the extinction coefficient

Working principle



Factors affecting the uncertainty of the reference absorption

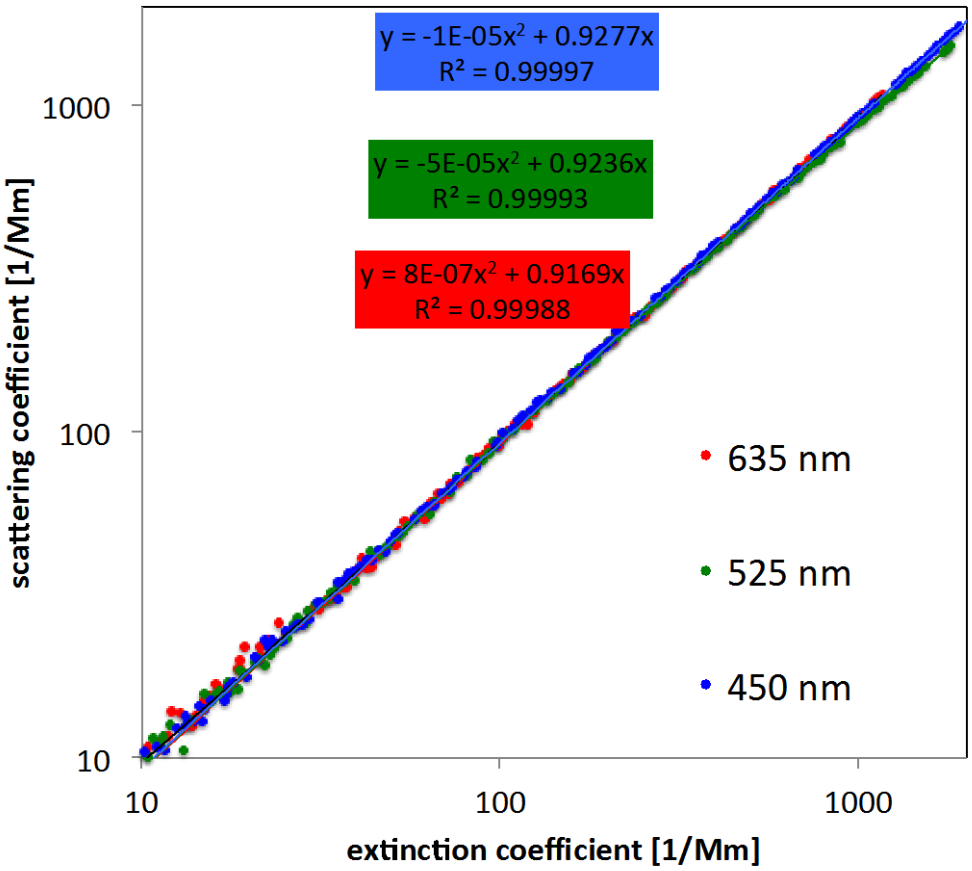
① effective cell length
② uncertainty of CO_2 calibration
③ truncation correction
④ Wavelength interpolation
⑤ Particle transport losses
⑥ Adjustment factor
⑦ Zero drift

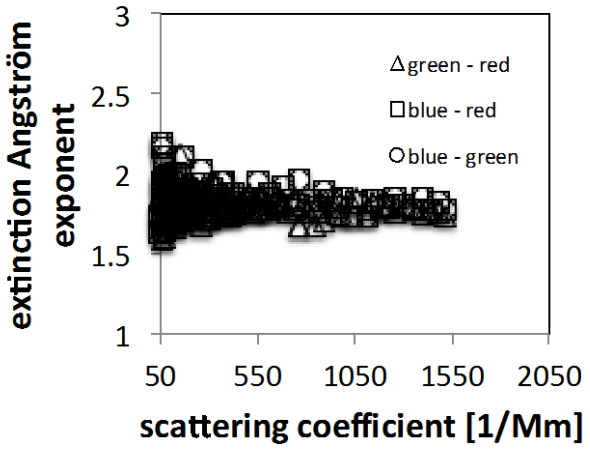
Furthor factor affecting the precision of intercomparsion

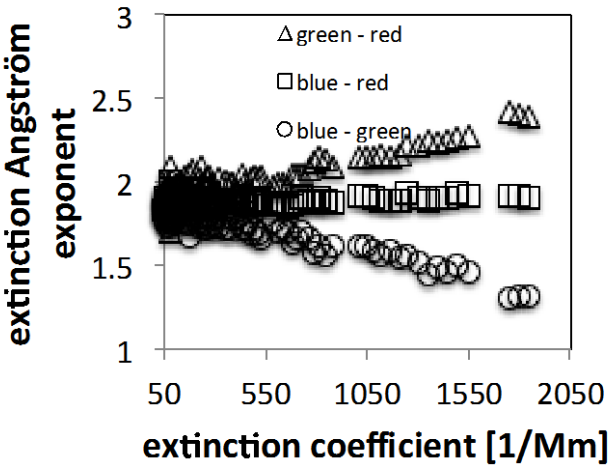
a. CAPS noise
b. Aurora noise
c. AE33 noise
d. MAAP noise

CAPS and Nephelometer tests using ammonium sulfate

Truncation correction scattering vs. extinction coefficients







- Nonlinearity of CAPS must be corrected for
- CAPS is about 7-8% lower than Nephelometer

'Calibrations of CAPS'

- Massoli et al. (2010) confirmed CAPS to be precise within 10%.
- Petzold et al. (2012) tested CAPS using PSL & Mie calculations.
  - The recalibration showed that the **extinction is low by 5%**. A factor of 1.05 was included in the firmware of all CAPS.
- Laboratory experiment (Sep to Nov 2015) at TROPOS. Experiments with ammonium sulfate showed that **extinction is about 6-7% higher** than scattering measured by Nephelometer.

Possible reason for discrepancy

- Petzold et al (2012) showed Mie scattering calculations with fitted log normal size distributions. The **standard deviation of fitted modes might be too large**, since the sizing instrument (OPC, Grimm 1.129) can not resolve PSL size distributions.
- Recalculation of data (see Tab. 2 in Petzold et al., 2012), but with typical standard deviations for PSL of 3%
  - **Extinction calculated with fitted size distributions is 5% higher than with a narrow PSL size distribution.**

Uncertainty of the Reference Absorption System

Scattering
Nephelometer

Calibration error
- Purity of calibration gas
- …

➢ Error about 3%

Error of truncation correction ΔC_{ts}
- Light source geometry factors
- Aerosol phase function (refractive index, size, etc.. <=> requires iterative processing)

➢ Error approx. 5% (Bond et al. 2009)

Extinction
CAPS

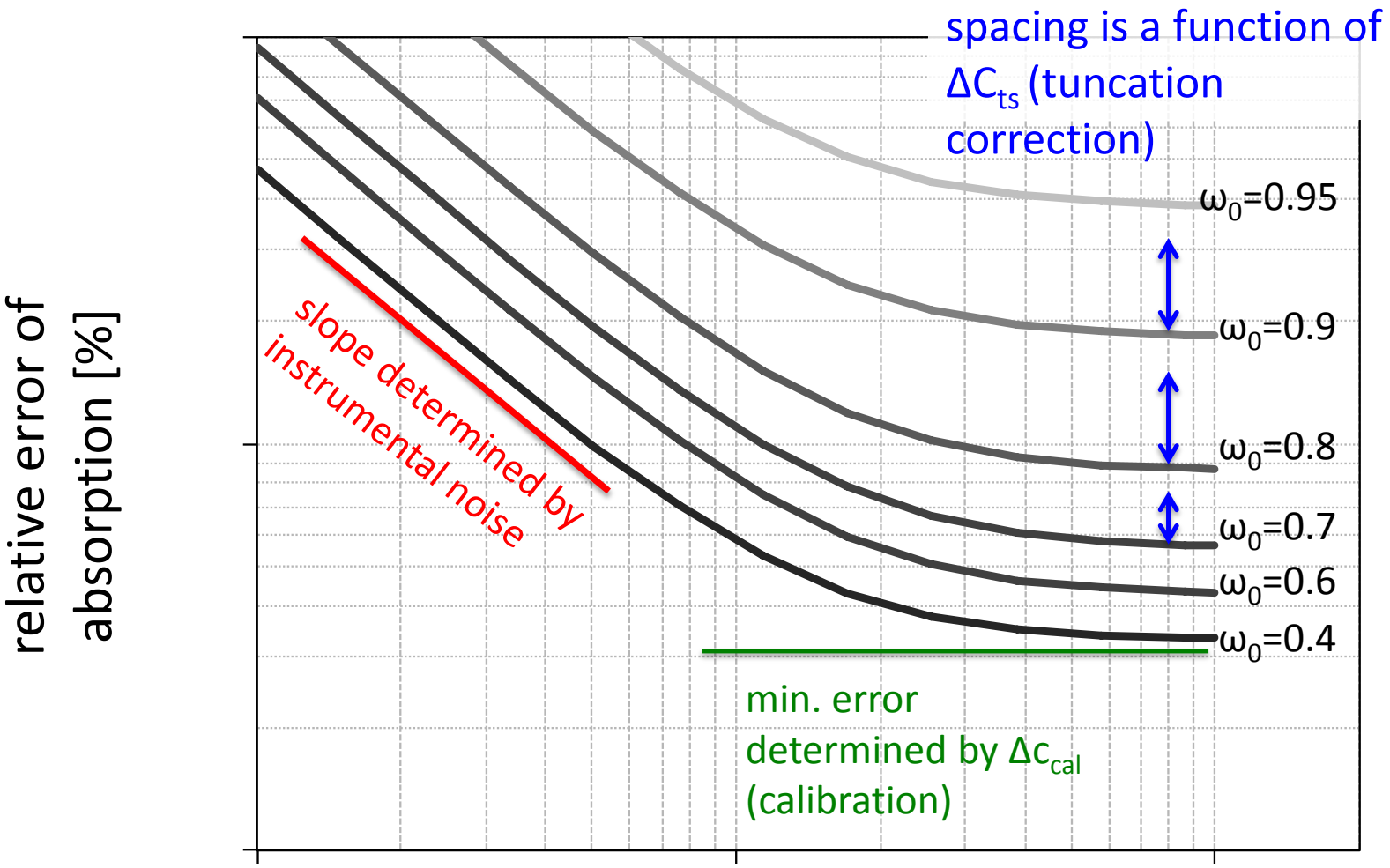
Calibration error ΔC_{cal}
- Effective path length error about 7 % ?

➢ Can be minimized to about 3% by coupling to Nephelometer.

Absorption
=Extinction - Scattering

Total error approx. 8%

Uncertainty of the Reference Absorption System



Traceability of reference absorption to SI

Nephelometer scattering: factors that need to be considered

- Rayleight scattering of calibration gas
- Truncation correction can be calculated
  - geometrical factors (cell design)
  - simple polar intensity measurement (light source)
  - Mie scattering calculation for well know particles (e.g. PSL, NIST traceable)

CAPS extinction: factors that need to be considered

- Attenuation of light beam measurement transformed to a phase shifted signal (linearity ?)
- Effective path length can be 'calibrated' by adjusting to scattering (nephelometer)

Does the reference absorption system fulfil the requirements to be 'SI traceable' ?

Calibration/-checks of the Reference Absorption System

Calibration type	Interval	uncertainty
Zero check of CAPS	15 minutes	0.1 Mm^{-1} higher for 'red' CAPS
Zero check of Nephelometer	daily	0.1 Mm^{-1}
Nephelometer calibration (CO_2)	weekly	<3%
Check of CAPS effective pathlength factor	weekly	<3%

On basis of about 6 weeks continuous measurements the reference absorption system was stable within the uncertainty.

More calibration cycles needed for assessing the long term stability.