Sino-German Symposium on
"Soot and its Climatic, Environmental and Health Impacts"

Choosing the proper technique for measuring the particle light absorption

Development of an 'absorption reference'

Thomas Müller
Leibniz Institute for Tropospheric Research
Leipzig, Germany

Mitglied der Leibniz-Gemeinschaft

Beijing, 27-30 June, 2016

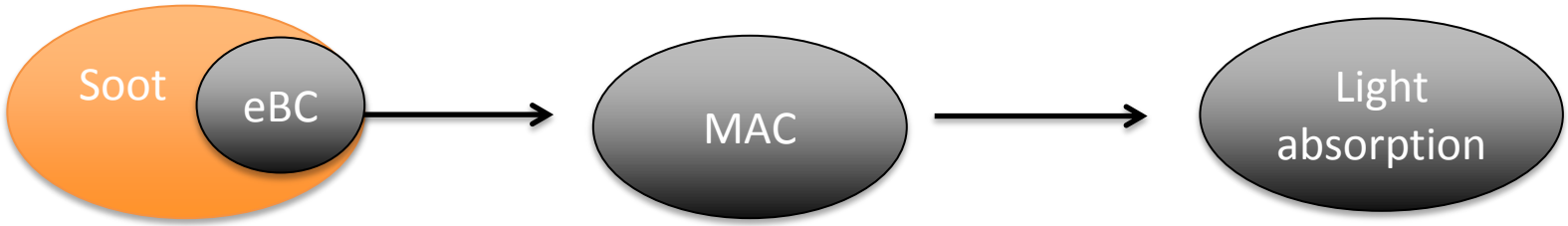
TROPOS
Leibniz Institute for Tropospheric Research

Relation between soot and light absorption

Soot: Particles composed of carbonaceous matter. Defined by physicochemical properties.

Light absorption is a fundamental physical process

Equivalent Black Carbon (eBC): Light absorbing part of soot



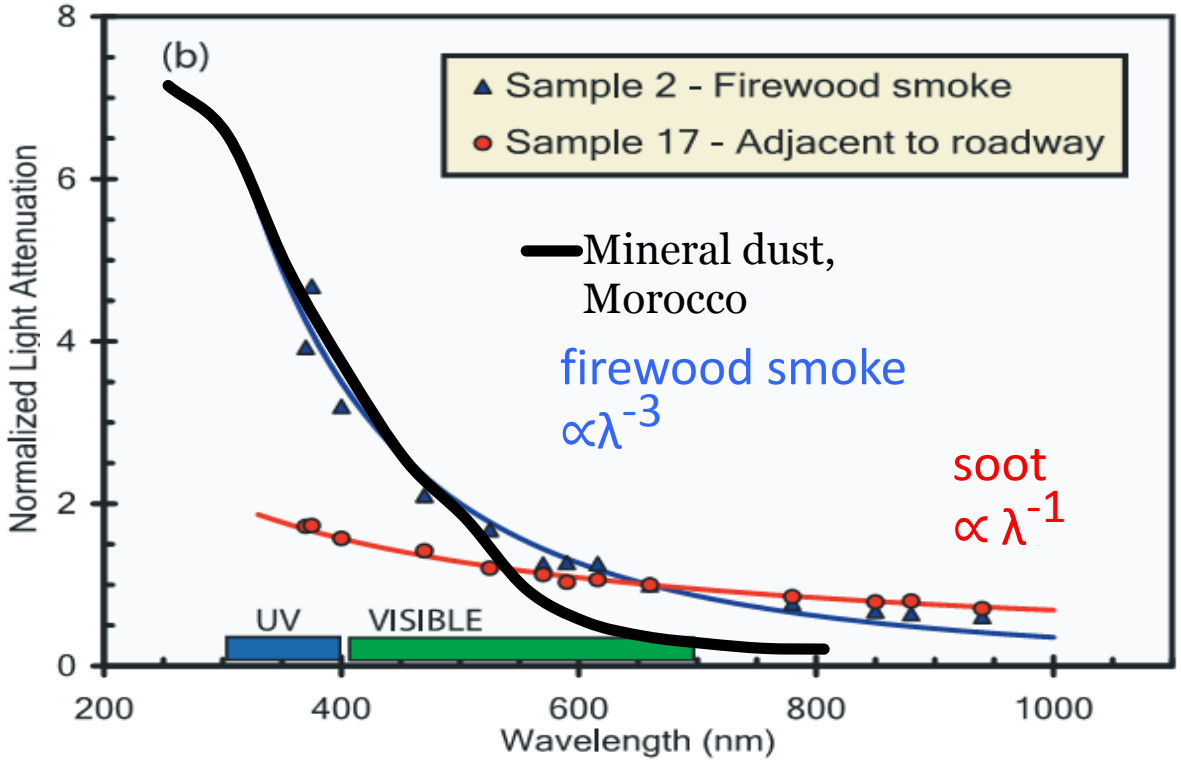
Mass Absorption Coefficient (MAC): Proportionality factor between eBC and light absorption. Depends on size, composition, morphology, etc.

Many instrument measure light absorption and report eBC concentrations using prescribed MACs !

TROPOS

Spectral absorption

- Beside soot, there are more light absorbing particles.
- Mineral dust, firewood smoke absorb light, but with a MAC lower by orders of magnitudes compared to soot.



Compiled from Kirchstetter et al. 2004 and Müller et al. 2009

TROPOS

Todays knowledge on the mass absorption coefficient

- Large uncertainties in the past due to missing standardization for measuring soot/eBC mass concentration and absorption coefficients.
- Recent works made significant progress (c.f. presentations G. Spindler and A. Wiedensohler, Zarnatta et al., submitted to ACP)

  One key was the standardization and harmonization of methods for measuring mass concentrations and absorption in the framework of the projects EUSAAR, ACTRIS.

- Data on spectral mass absorption coefficients are sparse. The main reason is a lack of reliable spectral absorption measurement.
- Need for standardized measurements and reference methods for light absorption.

TROPOS

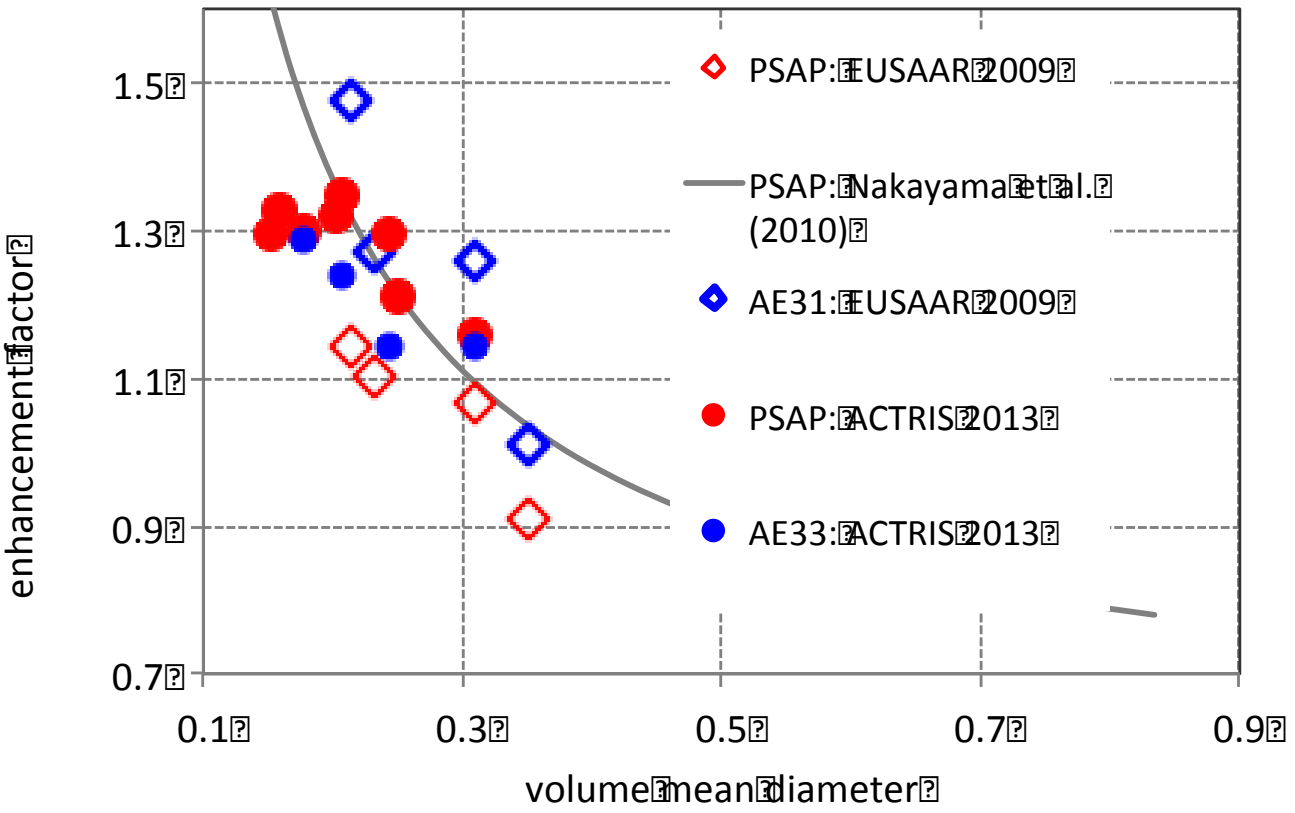
ACTRIS (European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases)

Activities related to particle light absorption

- Most data from field campaigns and monitoring stations are measured using filter based absorption photometers (MAAP, PSAP, Aethalometer, etc…)
- Filter based absorption measurements are subject to artefacts: multiple scattering enhancement, shadowing effect, scattering artefact,…
- Activities:
  - Quality assurance for instruments at the ECAC (European Center for Aerosol Calibration, TROPOS hosts laboratory for optical aerosol properties).
  - Development of corrections for filter based absorption.

TROPOS

Example: Artefacts of filter based measurements



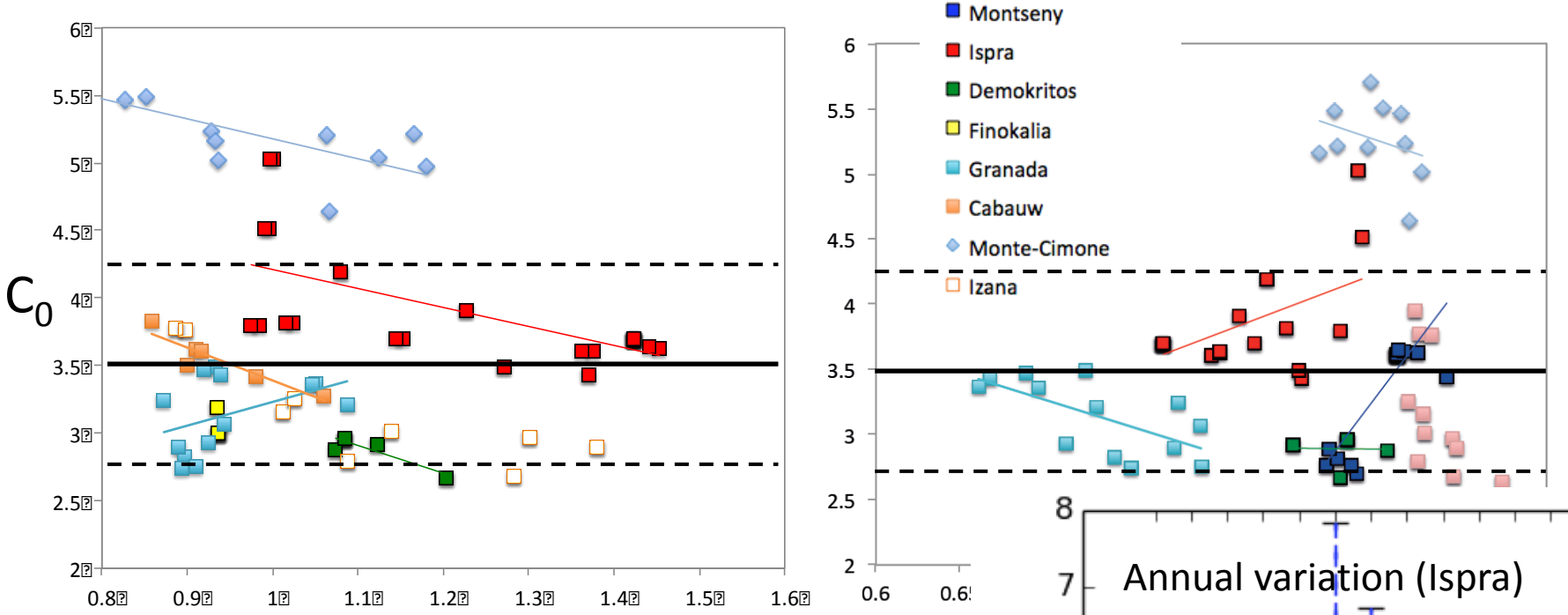
Sensitivity of PSAP and AE31 & AE33 Aethalometers depends on particle size.

TROPOS

Example: Aethalometer (AE31) artefacts

C_0: Factor for conversion of attenuation to absorption coefficients.

C_0 was determined for eight stations by comparing to MAAP



Recommended value: C_0=3.5 ± 0.875 (25%)

Activities within ACTRIS related to absorption (continuation).

- Development of corrections requires an *accepted reference method*.
- Possible reference methods
    - Photo-acoustic photometers (c.f. presentation M. Schnaiter)
    - EMS (Extinction minus Scattering)

Criteria for choosing a reference method

- Precision (smallest observable change in value, “detection limit’)
- Accuracy (closeness to the ‘true’ value)
- Do we know all sources of systematic errors and can correct for it?
- SI traceability: unbroken chain of calibrations to Si units

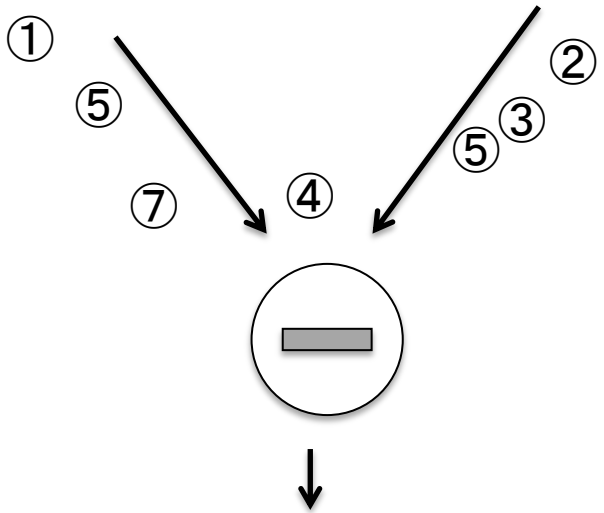
TROPOS

EMS method was chosen as reference method for the European Center for Aerosol Calibration (ECAC)

- Extinction measured by three CAPS (Cavity attenuated phase shift)
- Scattering measured by means of an three wavelength nephelometer (Aurora4000)

CAPS

Nephelometer



Factors affecting the uncertainty

① effective cell length
② uncertainty of CO_2 calibration
③ truncation correction
④ wavelength interpolation
⑤ Zero drift

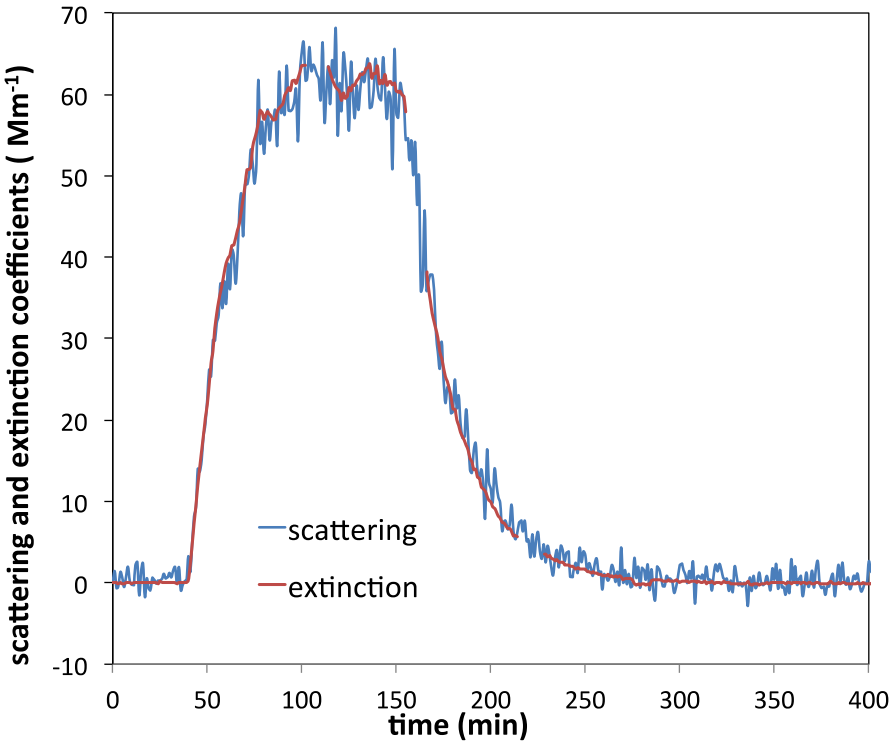
Factors affecting the precision (detection limit)

a. CAPS noise
b. Nephelometer noise

TROPOS

Test of CAPS and Nephelometer

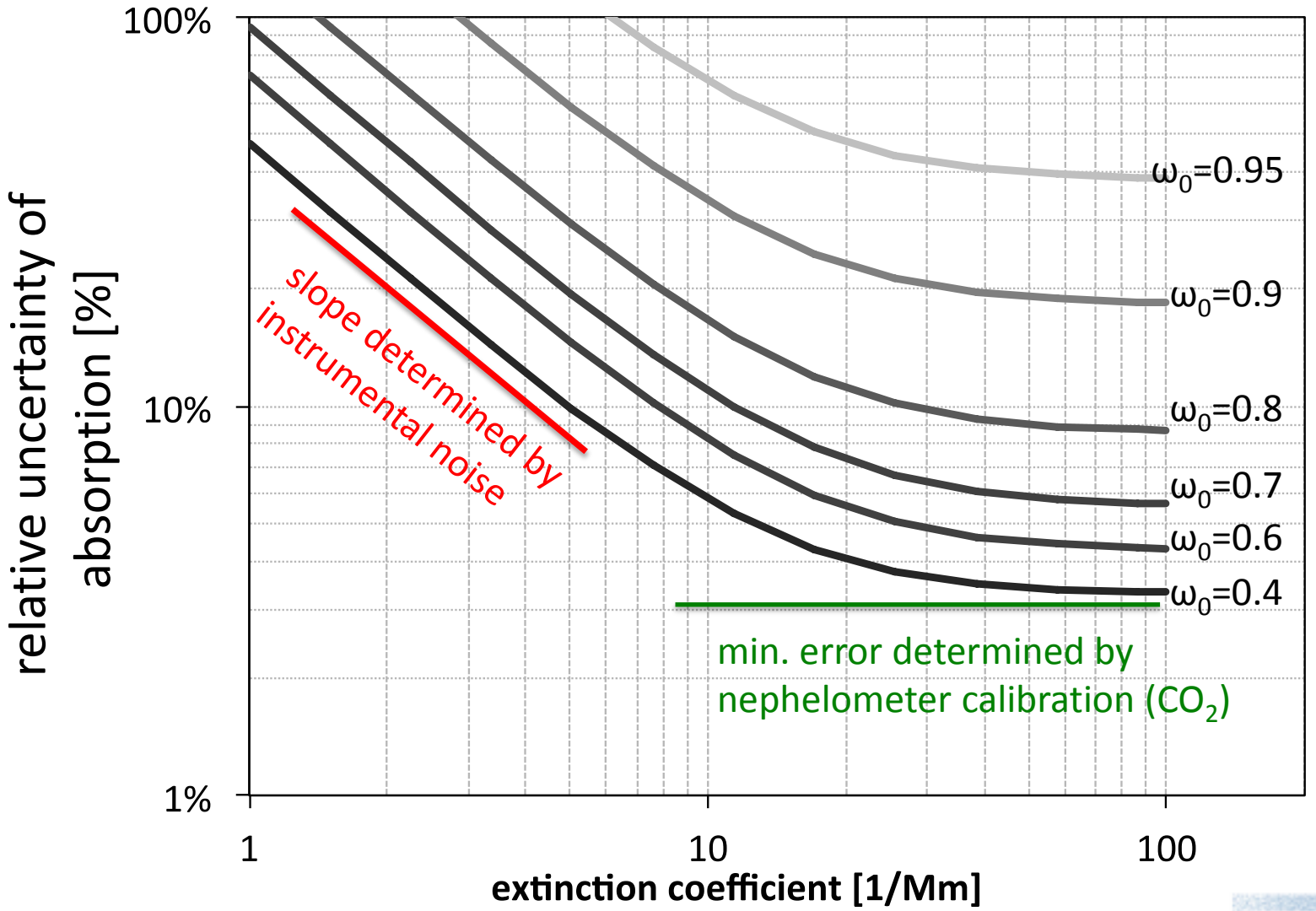
For non-absorbing particles follows: extinction equals scattering



- **Instruments agree with in 2%.**
- **U**ncertainty of CO_2 calibration of Nephelometer about 3%

TROPOS

Uncertainty considerations



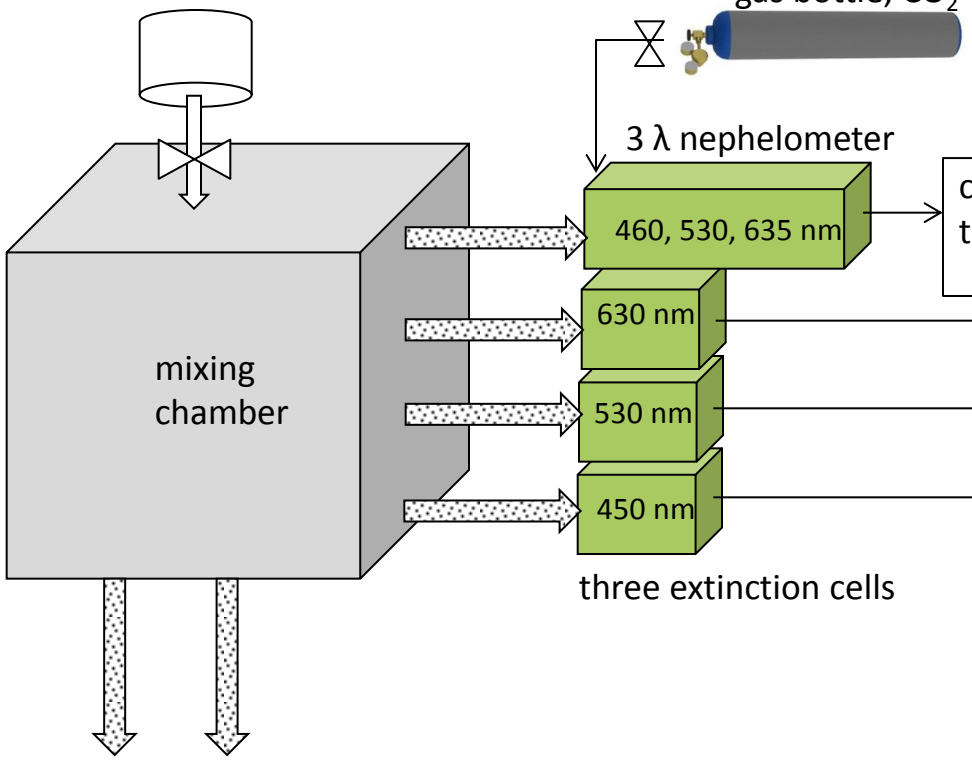
TROPOS

ECAC reference absorption setup

Calibration and Characterization

Aerosol generators for
- ❑ non absorbing particles
- ❑ absorbing particles

Ambient air inlet



corr. for truncation

1. Calibration
   - gas calibration
   - white particle check
2. Noise
   - particle free (filtered) air
3. Repeatability
   - repeat steps 1-3
4. Derive precision and accuracy

Reference Absorption
=
extinction - scattering

Outlets ports for other instruments

TROPOS

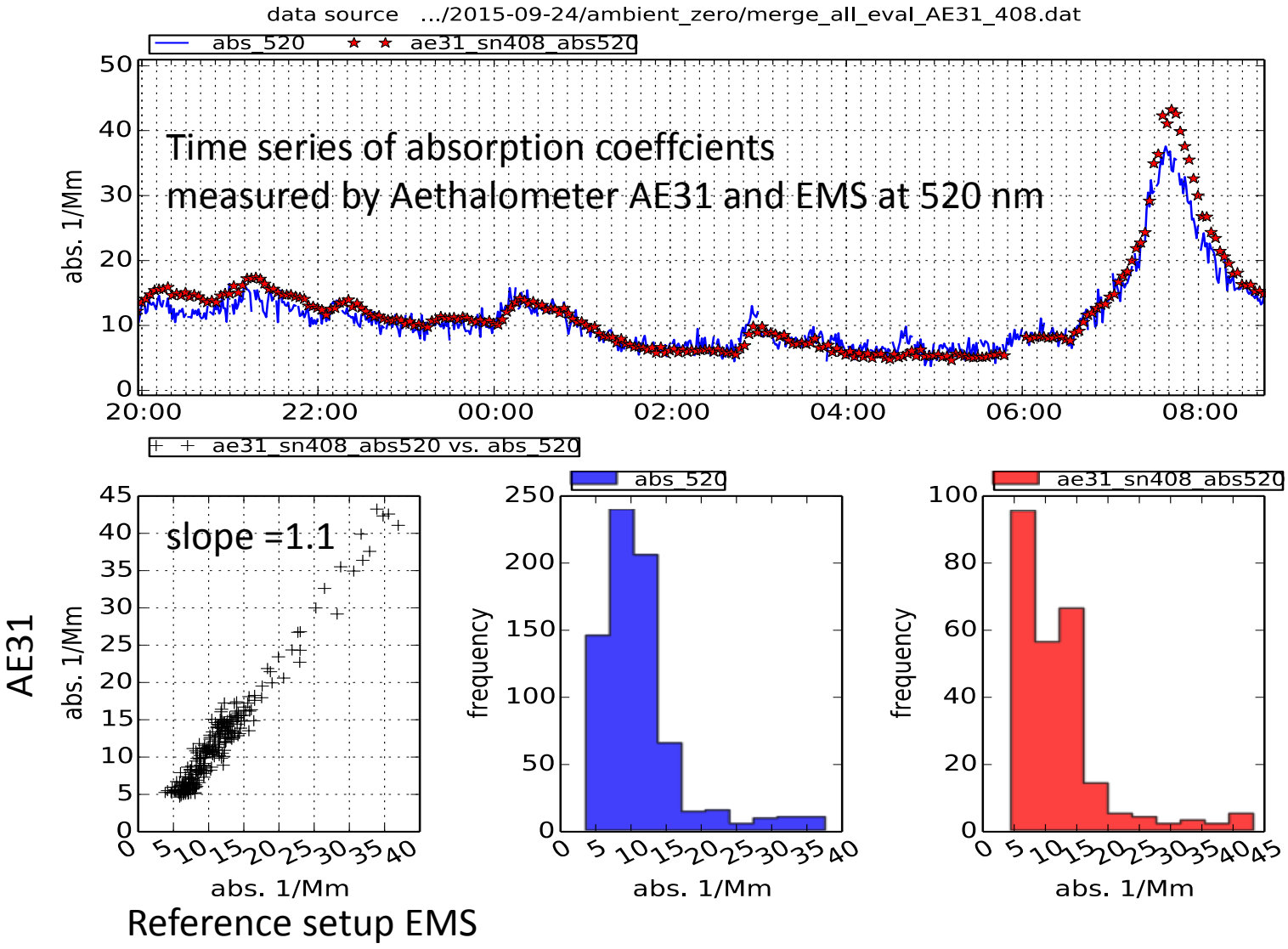
Calibration-checks and baseline adjustments

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 and calibration checks, the reference absorption system was stable within the uncertainty.

TROPOS

Typical results from ECAC intercomparison workshops



Comparison of methods and applications

	Accuracy	Precision	Temporal resolution	SI traceable	Size/weigh	Limitations	possible Applications
Filter based photom.	+	+++	1 to 60 secs	no	from pocket size to rack mount	multiple scattering enhancement , shadowing effect, Scattering artefact…	• Monitoring • Mobile measurements • Aircraft, tethered balloon
Photo acoustic photom.	++(+)	+++	1 to 60 secs	(?)	rack mount	gas calibration sensitive disturbances	• Monitoring • Secondary reference • Aircraft
Extinction minus scattering	+++	+	60 secs	yes	Large rack/laboratory	Requires high conc. (ext.>20 Mm^{-1}) ssa < 0.95	• Lab studies • Primary Reference for calibrating / characterizing experiments

bad + fair ++ good +++

TROPOS

Summary

- *Filter based instruments* are often used for monitoring applications (size and operation costs).

- *Extinction minus Scattering* is a SI traceable laboratory setup. It can can be used to for calibrating other instruments. Difficult to operate in the filed.

- *Photo acoustic photometers* could bridge the gap between monitoring and lab instruments.

TROPOS