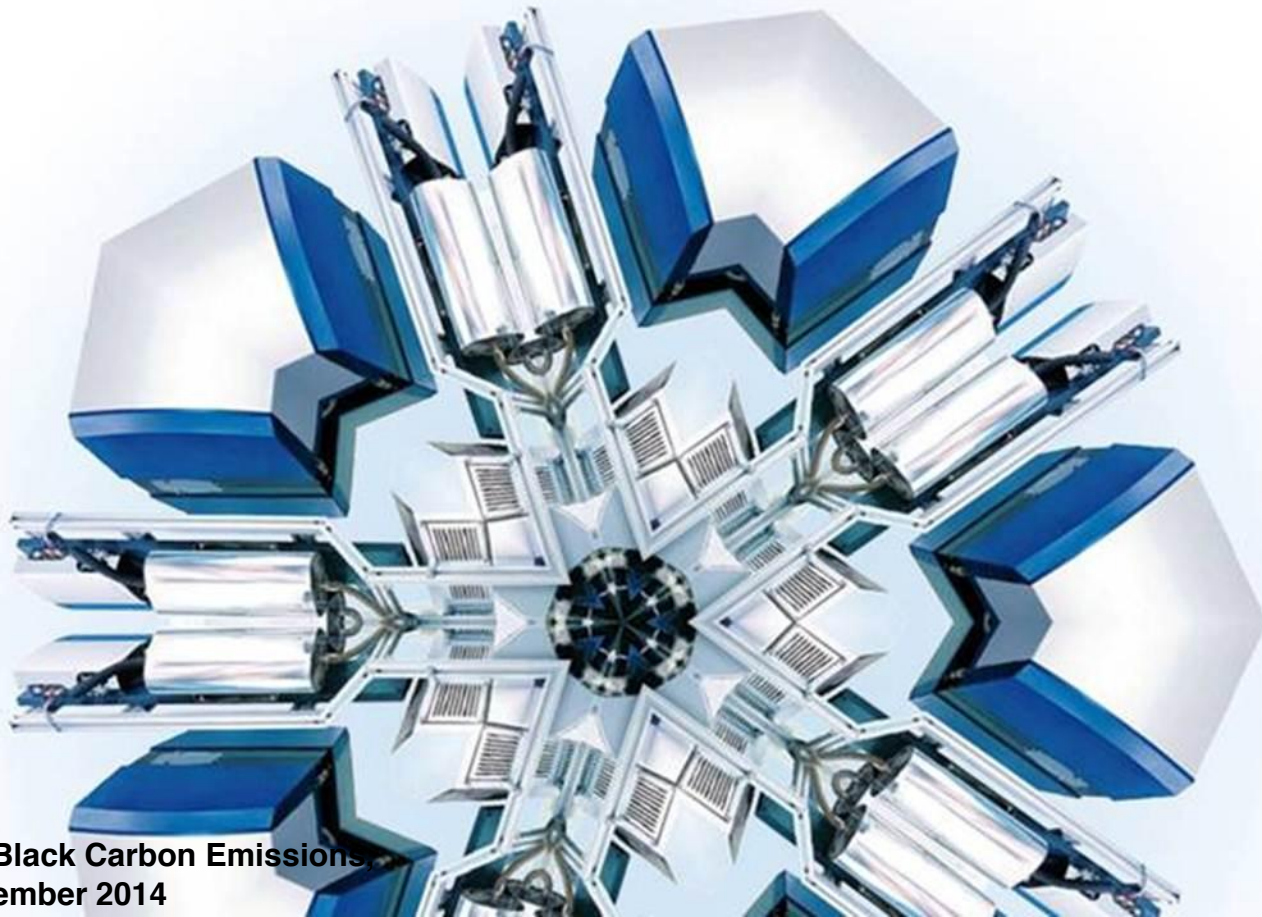


INSTRUMENTATION FOR MARINE BLACK CARBON MEASUREMENTS



Outline

- IMO Measurement Methods and Definitions for Black Carbon

- Selectivity of Different Instruments

- AVL Instruments to Measure the Mass of Light-absorbing Particles from Marine Engines
 - AVL 415 Smoke Meter
 - AVL 483 Micro Soot Sensor (MSS)
 - Correlation Filter Smoke Meter 415SE - MSS
 - Correlation Filter Smoke Meter 415SE - MAAP

- Conclusions

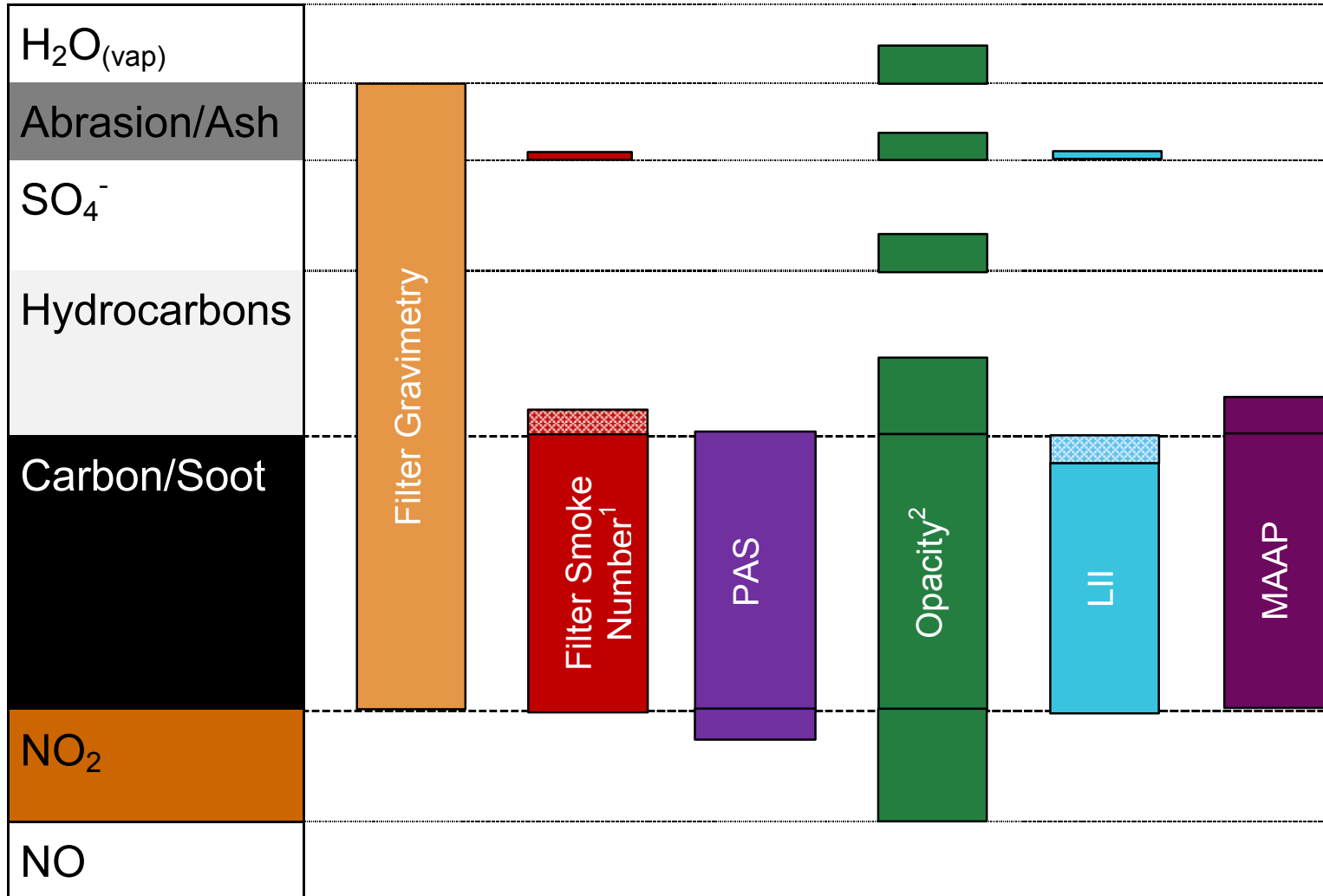
Measurement Methods for BC

- The MEPC technical committee should decide a definition for BC as being either equivalent Black Carbon (eBC) or Light-absorbing Carbon (LAC)¹.
- The following methods were selected as appropriate for the proposed definitions:

Equivalent Black Carbon (eBC):	Light-Absorbing Carbon (LAC)
Filter Smoke Number (FSN)	Filter Smoke Number (FSN)
Multi Angle Absorption Photometry (MAAP)	
Photo-Acoustic Spectroscopy (PAS)	
Laser Induced Incandescence (LII)	

¹According to PPR1/WP.5 dated 6th of February 2014.

Selectivity of Different Instruments



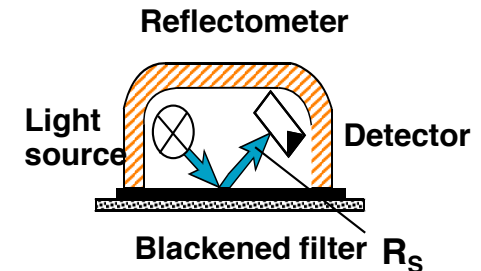
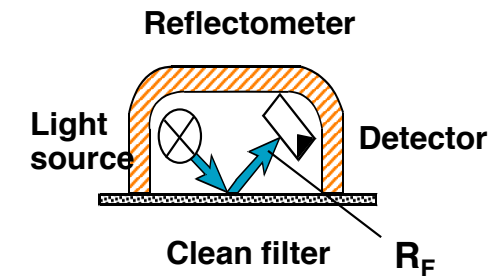
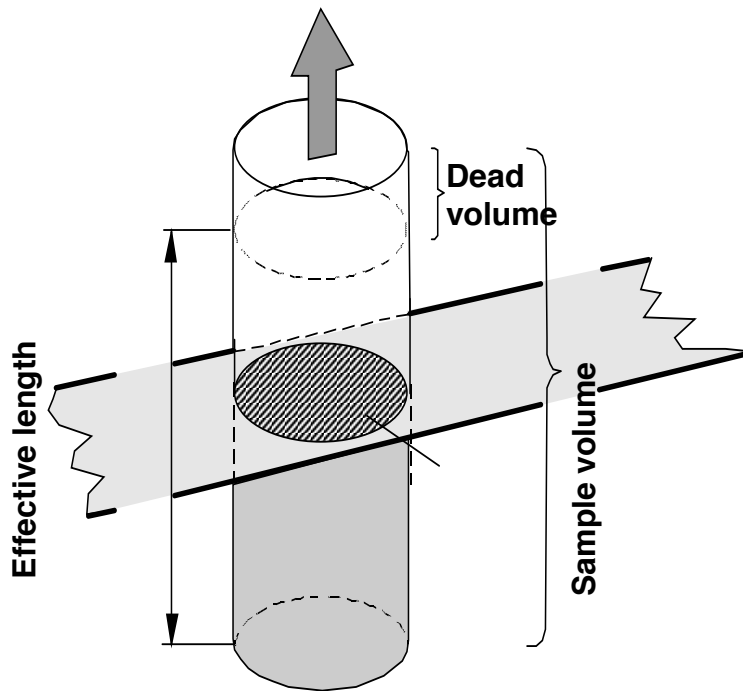
¹Filter Smoke Number is a standardized method conform ISO 10054

²Opacity is a standardized method conform ISO 11614

AVL Instruments to Measure the Mass of Light-absorbing Particles from Marine Engines

AVL 415SE Measurement Principle

- Measures the reflection of visible light from a soot loaded filter surface.
- The instrument samples a user defined volume of exhaust gas and draws it through a clean filter paper.
- The filtered “soot” causes blackening of the filter paper which is detected by an optical measuring head.



$$\text{Effective length} = \frac{\text{Sample volume} - \text{Dead volume} - \text{Leak volume}}{\text{Filter area}}$$

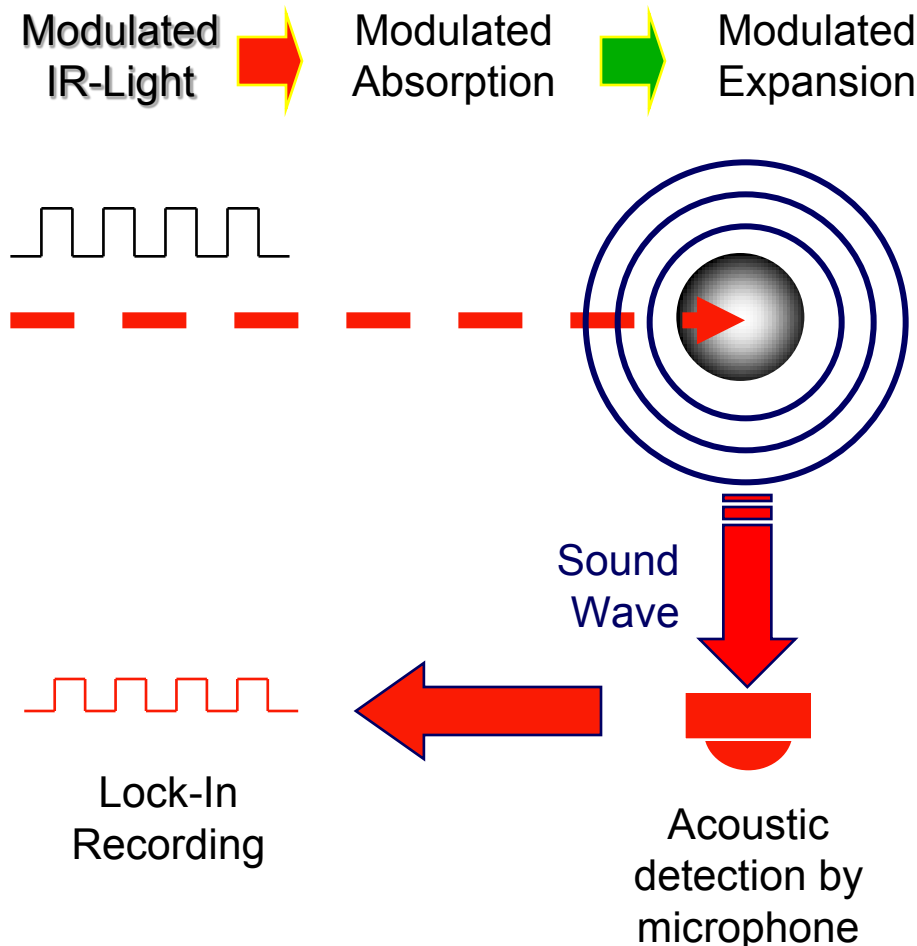
AVL 415SE – Filter Smoke Meter



- Is a well known established measurement method used for engine development and for production conformity tests (Is a standard emission equipment on each new engine test bed).
- Standardized method conform ISO 10054
- Filter Smoke Meter could be also installed on ships.
- Integral measurements of transient peaks with preselected sampling time for BC estimates on ship manoeuvres.
- High sensitivity through variable sampling volume. (can be parameterized from 2 seconds up to 2 minutes)
 - Current Resolution: 0.001FSN or 0.01 mg/m³
 - Detection Limit: 0.002FSN or ~ 20 µg/m³
- Robust instrument (against heavy fuel).



AVL 483 Micro Soot Sensor (MSS) Measurement Principle



- Sample diluted exhaust (CVS, SPC, or Conditioning Unit)
- Exhaust gas will be directed through a measuring chamber and thermally animated by a modulated laser beam
- Modulated heating produces periodic pressure pulsation, which will be detected by a microphone as acoustic wave
- Signal will be amplified in a pre-amplifier and filtered in a „Lock-In“- amplifier.

AVL 483 Micro Soot Sensor (MSS)



- The instrument is based on the photoacoustic measurement method
- Time resolved signal (Digital data rate up to 10Hz, rise time <1sec)
- High sensitivity ($5 \mu\text{g}/\text{m}^3$)
- High dynamic range: mg/m^3 to g/m^3 (up to $1 \text{ g}/\text{m}^3$ with dilution)

Micro Soot Sensor and Smoke Meter



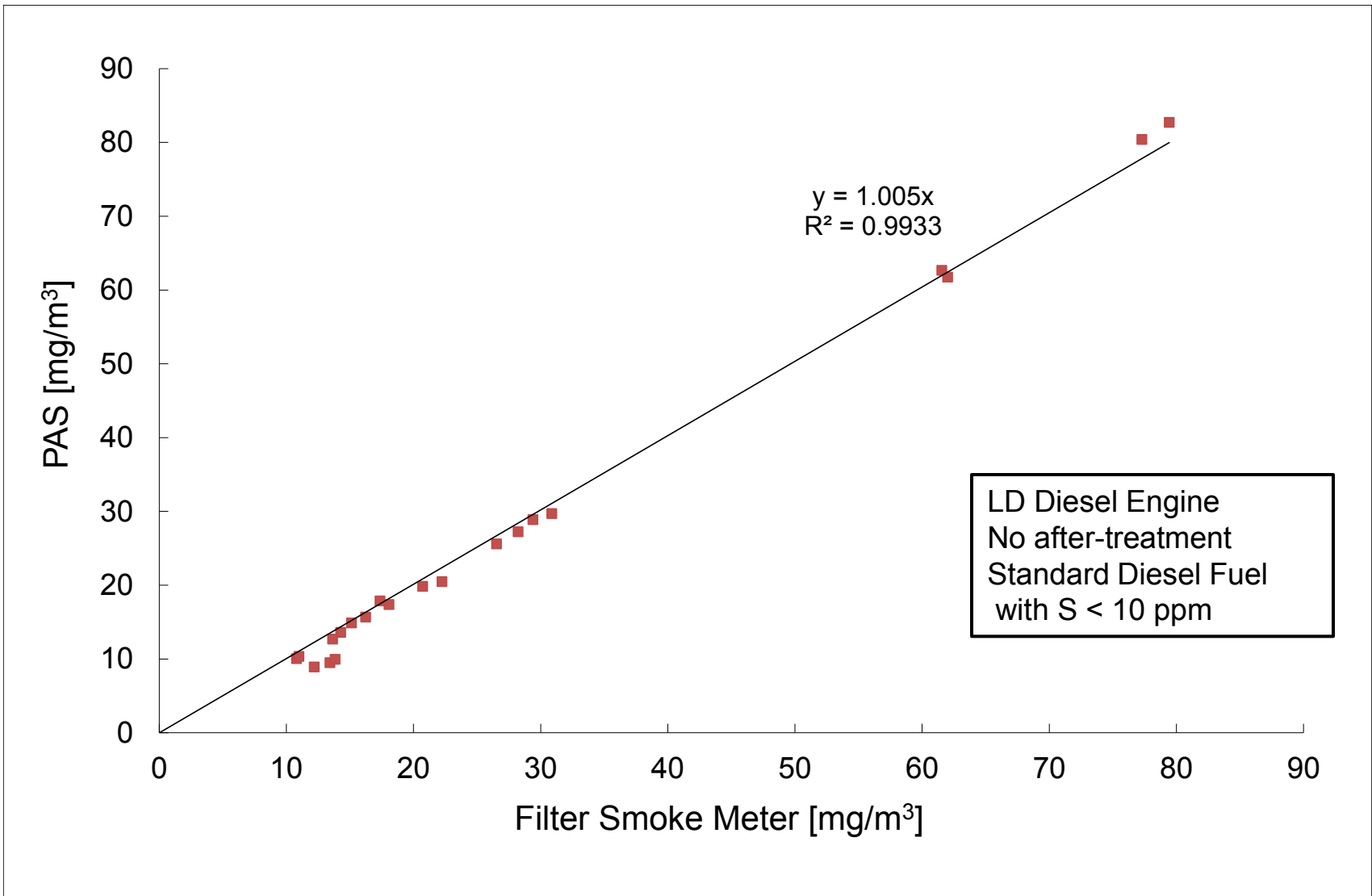
Instrument	Measurement Value	Principle	Detected Components
Micro Soot Sensor (MSS)	mg/m ³	Light absorption based on photo-acoustic method	Measures the 808 nm light absorbed by the particles. Carbon Soot “C” (“eBC”), “Black Smoke”
Smoke Meter (SM)	FSN and mg/m ³	Light absorption based on reflection method	Measures the reflection of visible light (absorbing eye response according CIE 69) from a soot loaded filter surface. Carbon soot “C” (“eBC”), “Black Smoke”

Measurements with 415 SE Smoke Meter are Reliable and Comparable with Data From Other Sources

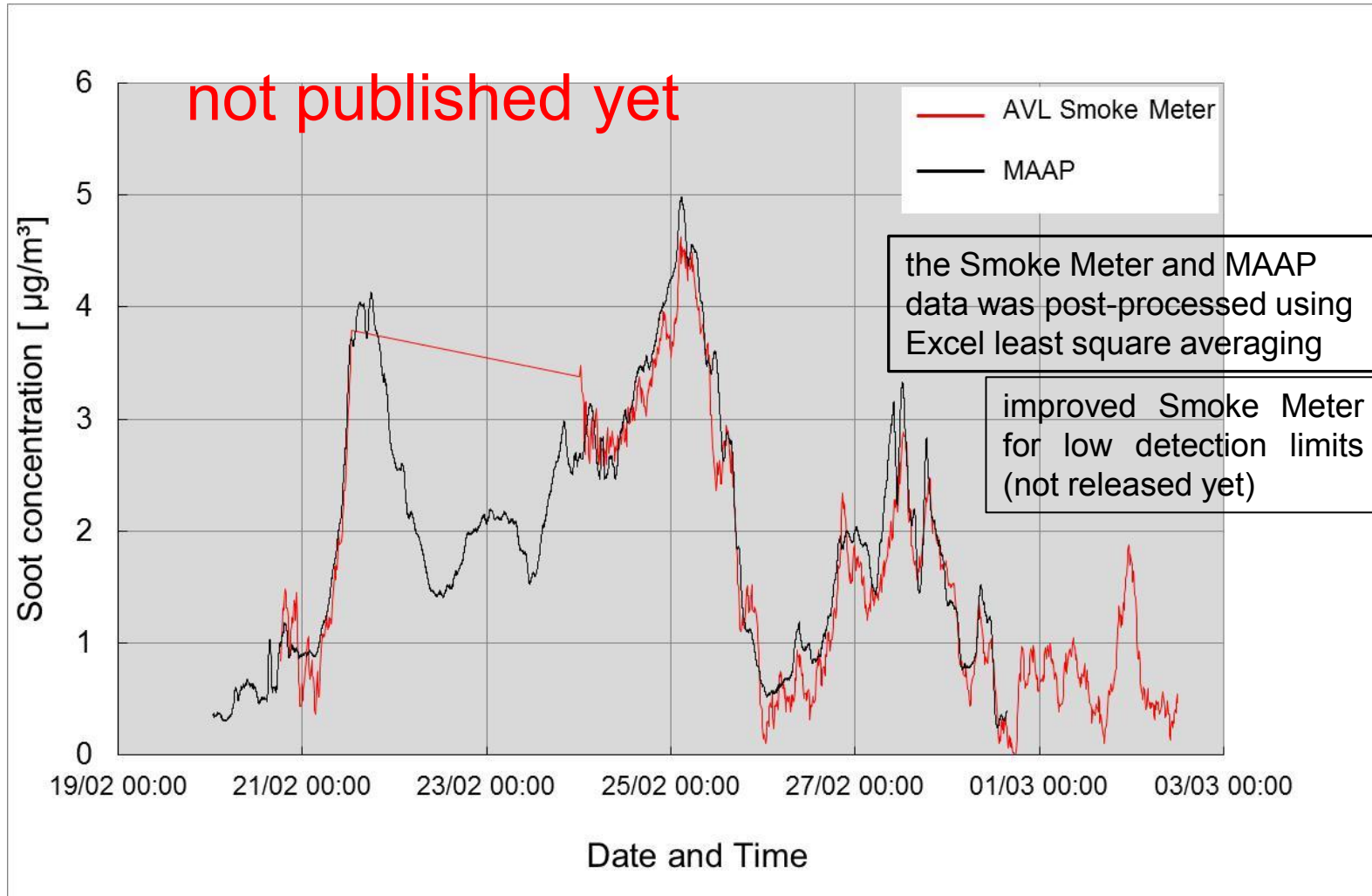


- eBC (equivalent Black Carbon) concentration derived from AVL filter smoke measurements correlates very well to the values given by PAS (Photo Acoustic Soot Sensor) and the ~ 1h average values of MAAP (Multi Angle Absorption Photometer).
 - Location and design of the sampling probe is essential in order to obtain consistent test results.

Correlation Smoke Meter 415SE - PAS



Correlation 415SE - MAAP



Data Source: ACTRIS Workshop Feb, 2013 at Leibniz Institute for Tropospheric Research (TROPOS)

Conclusions



- Filter Smoke Meter measures the reflection of visible light from a soot loaded surface.
- AVL Filter Smoke Meter correlates well to eBC only (not total PM).
- The AVL Filter Smoke Meter shows good correlation to PAS and MAAP.
- For on-board marine applications specific adaptations may be required.

Thank You For Your Attention!