PARTICULATE MATTER CONCENTRATION EVALUATION OF VAISALA'S AQT560 AGAINST MULTIPLE EQUIVALENCE REFERENCE METHODS

2024 New Orleans National Ambient Air Monitoring Conference

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AQT560

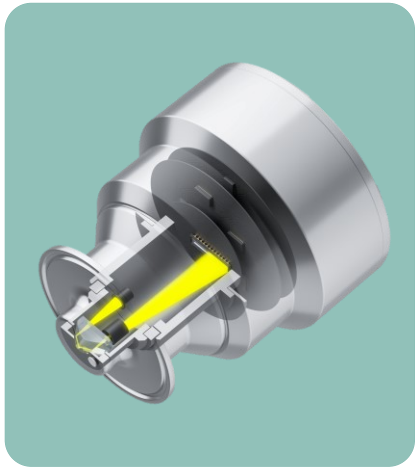
Vaisala Air Quality Transmitter

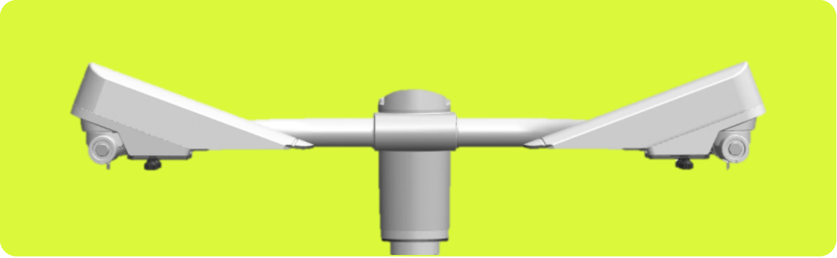
07:15 22 FEB	«	0.7 °C	88.8 %	0.01 ppm	0.03 ppm	0.09 ppm	0.01 ppm	12.9 µg/m³	5.9 µg/m³	4.7 µg/m³	17 EAQI
TIME & DATE		AIR TEMPERATURE	RELATIVE HUMIDITY	NO_2	NO	CO	O_3	PM_{10}	$PM_{2.5}$	PM_1	AIR QUALITY INDEX

VAISALA

Pioneering optical instruments since 1980's

Vaisala has been developing world leading optical and photonics instruments since the 1980´s, using, e.g., diode laser LIDAR technologies, infrared absorption spectroscopy, and proprietary optical MEMS components to achieve the best performing products.





Nearing reference grade performance for particle measurement

2024

LPC300

- 3rd gen. Laser Particle Counter Size range **0.3um-10um**
- Smart algorithms based on extensive amount of field data
- Re-designed sample air flow

2021

LPC200

2nd gen. Laser Particle Counter
Size range **0.6um-10um**

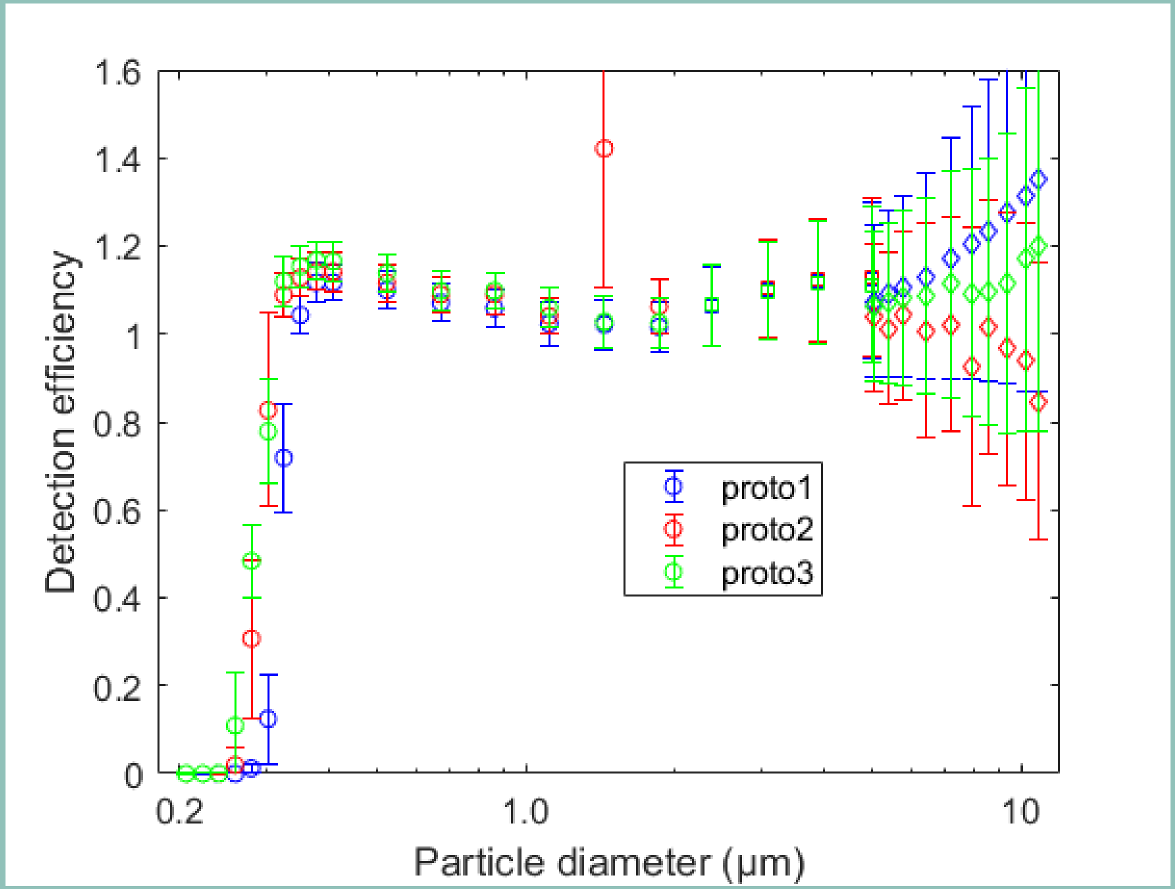
2017

LPC100

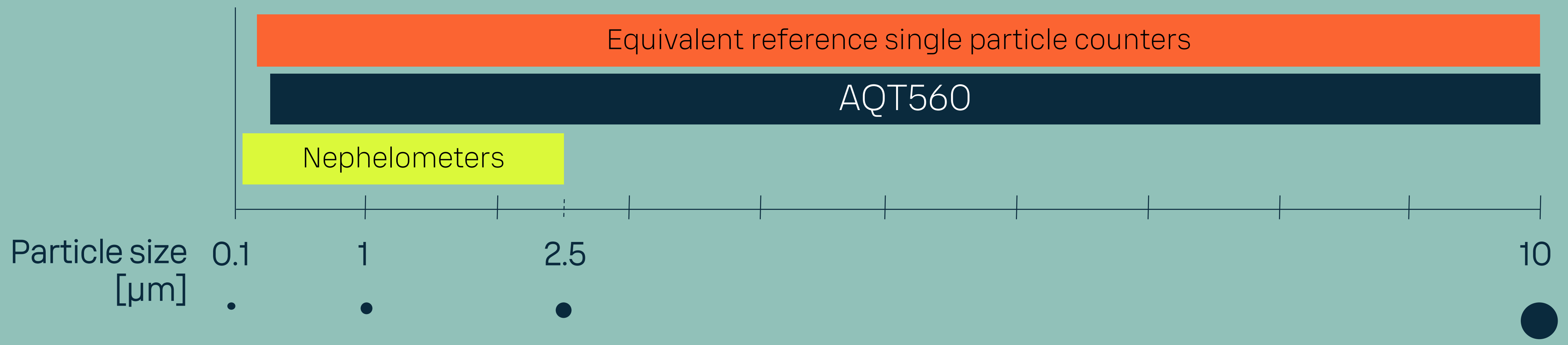
1st gen. Laser Particle Counter
Size range **1.2um-10um**

Detection efficiency tested at Tampere University (TUT)

Vaisala Laser particle counter:
- Lower detection limit at 300 nm
- Good efficiency up to 10 µm



Detection across the full range



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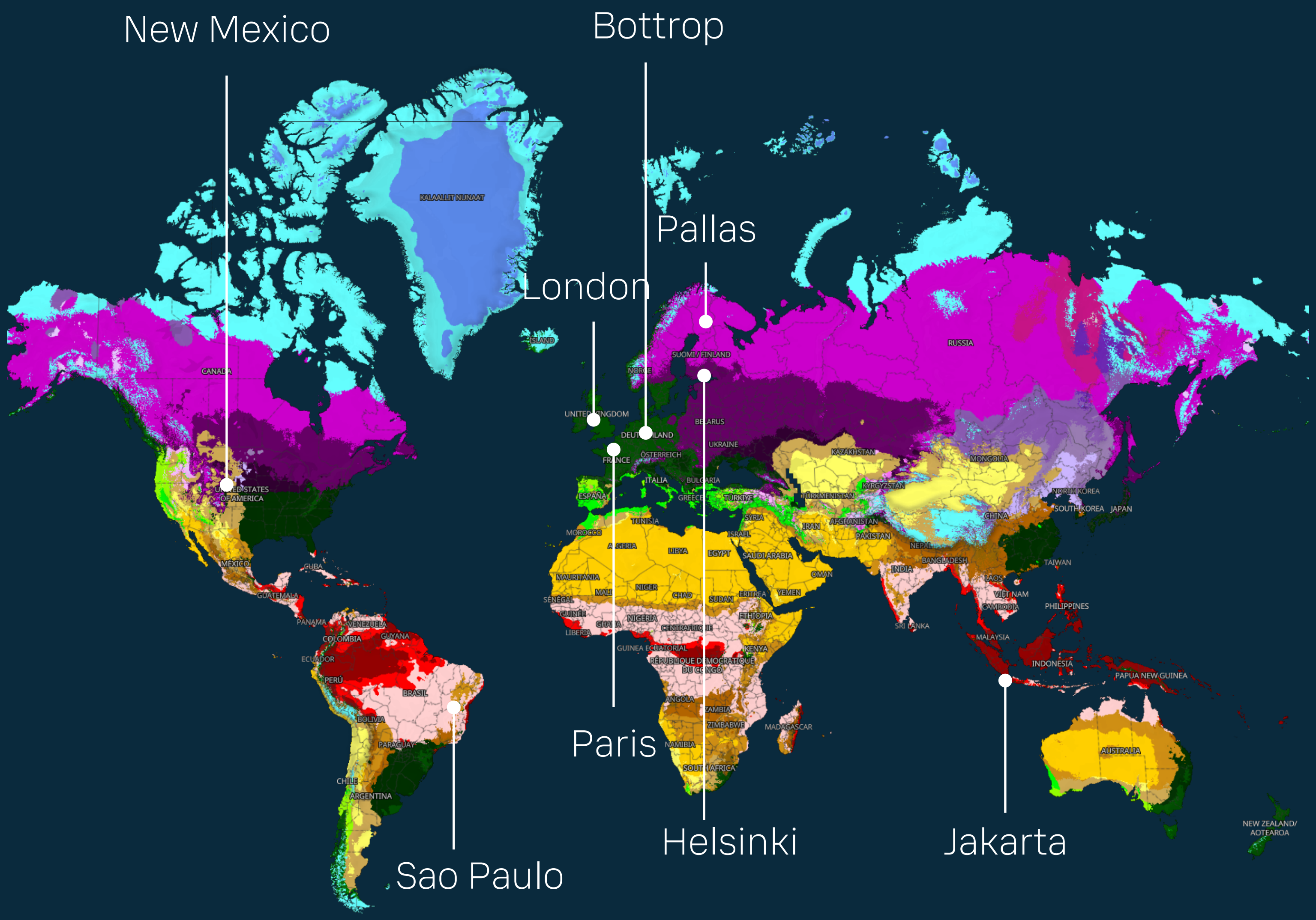
6 million hours of field data

From 6 climate zones



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Comparison setup

Multiple AQT560s are compared against 3 reference equivalence monitors for 1 Year

- Paris Traffic site
- Instrument BAM 1020, Met One, USA
- Method: Beta attenuation

- London Background / Airport
- Fidas 200, Palas, GER
- Method :Optical

- Helsinki Traffic site
- Fidas 200, Palas, GER
- Method: Optical

- New Mexico: Urban Background
- Fidas 200, Palas, GER
- Method: Optical

- Asian MegaCity
- TEOM AB, Thermo Scientific ,USA
- Method: Oscillating Micro balance

→ **With this in place it is possible to evaluate how accurate the AQT560 is in measuring particulate matter**

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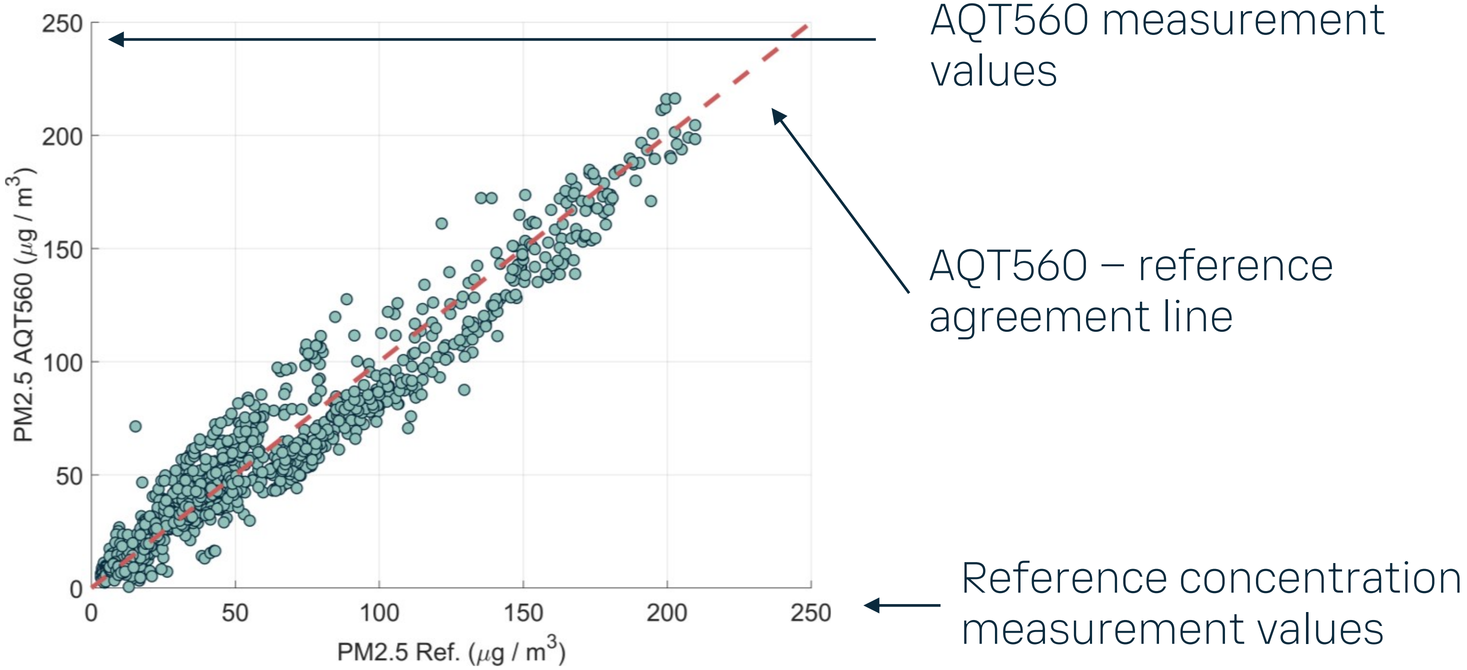
Concentration comparison to reference

- Ref.: TEOM
- 1-h mean, 6 months of data



Note: All AQT560 measurement values are based on factory calibration, **no** co-location corrections or model-based corrections are used in any tests

R^2 = 0.94
Slope = 0.93
MAE = 8.22
REU(at 50µg/m³) = 42.84%

R2 = co-efficient of determination, 1.00 is perfect agreement
Slope = Agreement between rates of change in concentration
MAE = Mean absolute error
REU = Relative Expanded uncertainty

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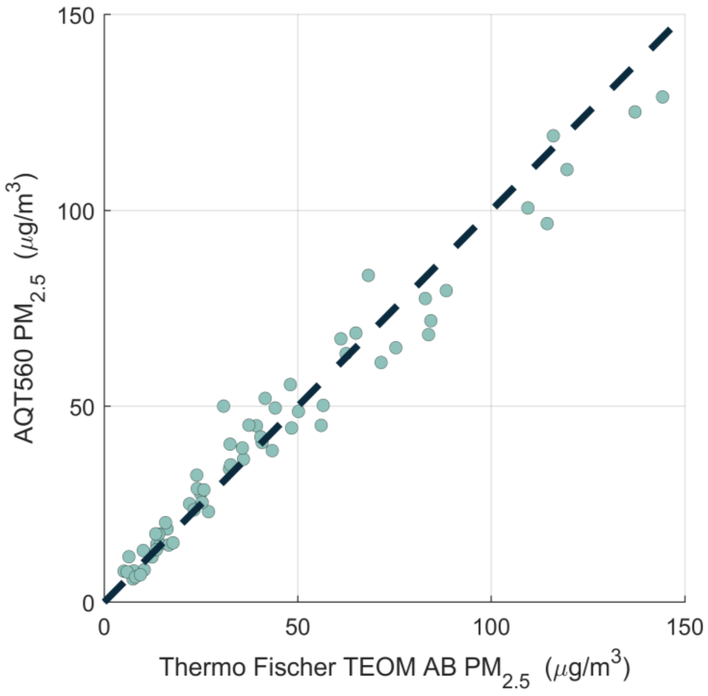
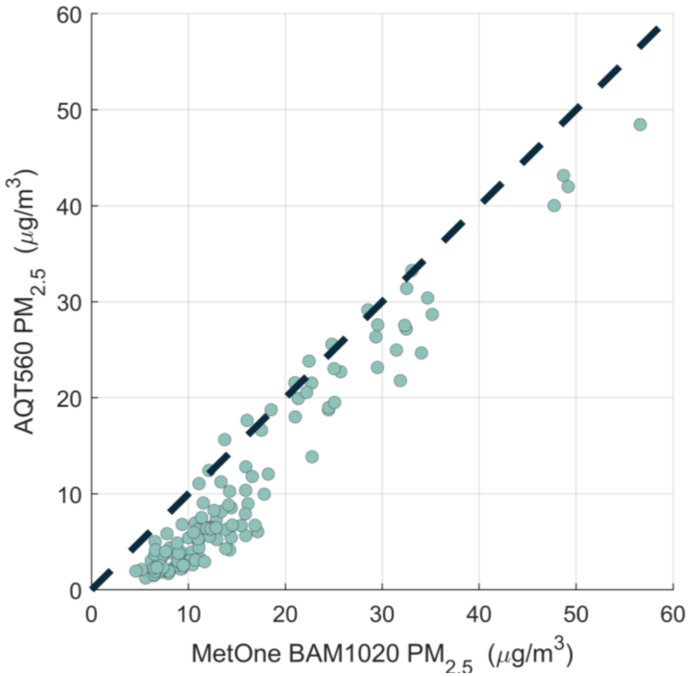
PM2.5 data in daily averages

- Ref.: TEOM
- 24-h mean, 6 months of data



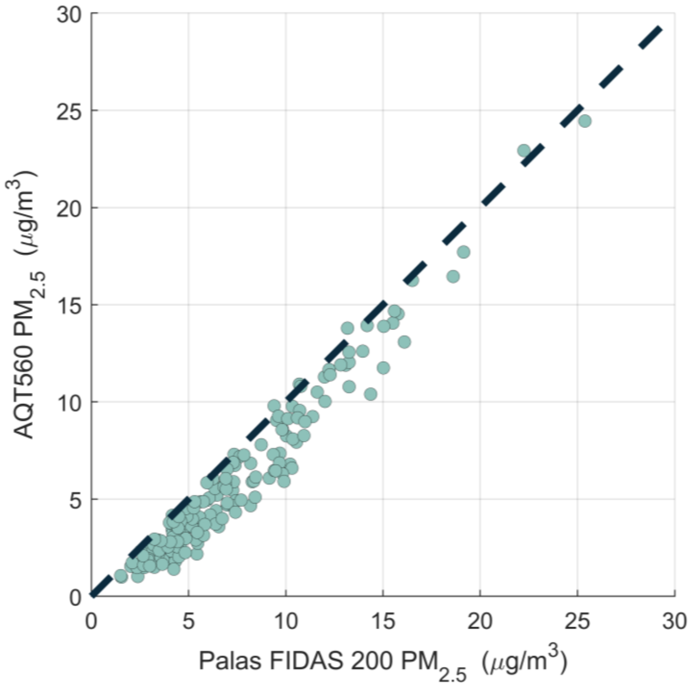
R^2 = 0.98
Slope = 0.92
MAE = 5.35
REU(at 30µg/m³) = 41.54%

- Ref.: BAM
- 24-h mean, 9 months of data



R^2 = 0..92
Slope = 1..04
MAE = 4..78
REU(at 30µg/m³) = 31.32%

- Ref.: Optical
- 24-h mean, 7 months of data



R^2 = 0.95
Slope = 0.97
MAE = 1.44
REU(at 30µg/m³) = 13.72%

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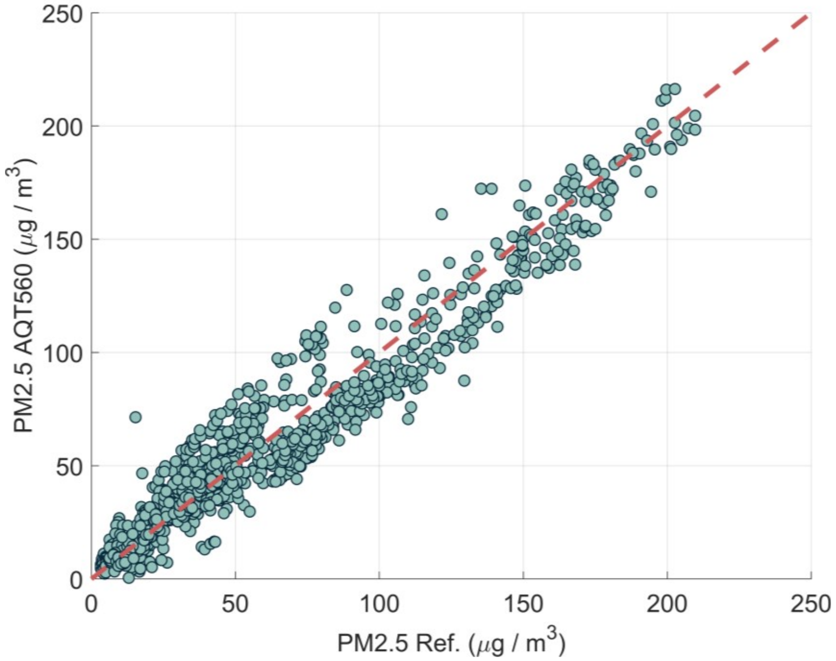
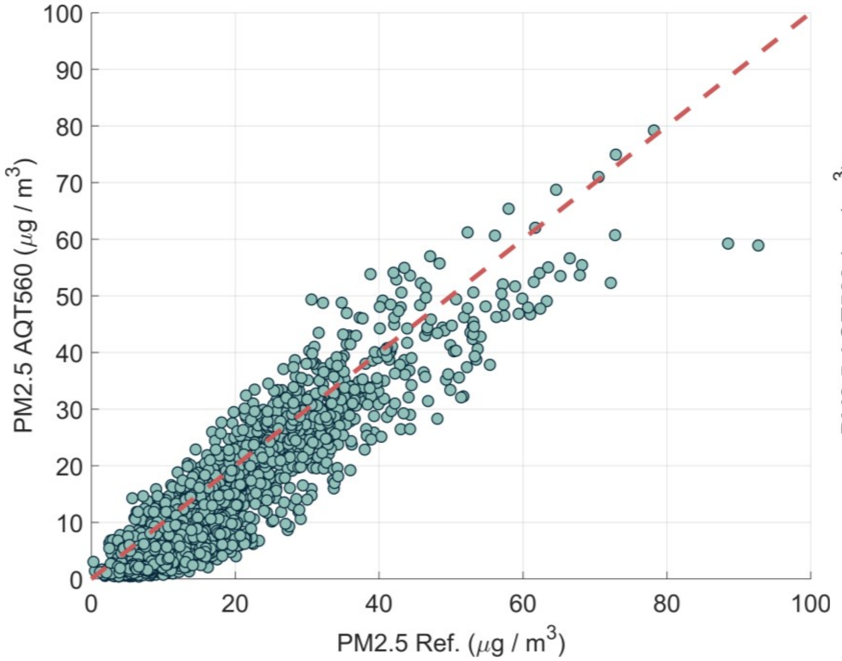
PM2.5 in different sites

- Ref.: TEOM
- 1-h mean, 6 months of data



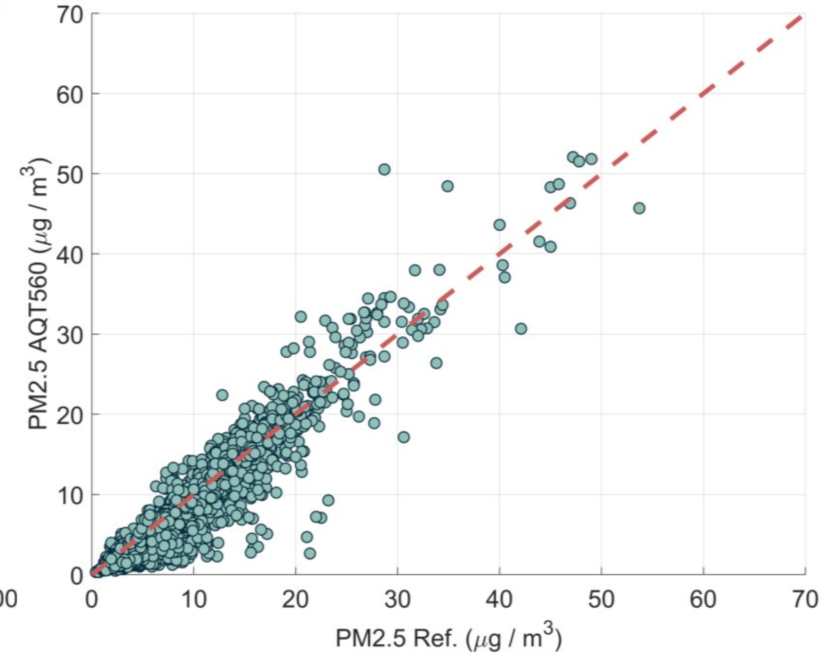
R^2 = 0.94
Slope = 0.93
MAE = 8.22
REU(at 50µg/m^3) = 42.84%

- Ref.: BAM
- 1-h mean, 9 months of data



R^2 = 0.84
Slope = 0.97
MAE = 5.39
REU(at 50µg/m^3) = 27.72%

- Ref.: Optical
- 1-h mean, 7 months of data



R^2 = 0.9
Slope = 1.02
MAE = 1.44
REU(at 50µg/m^3) = 6.32%

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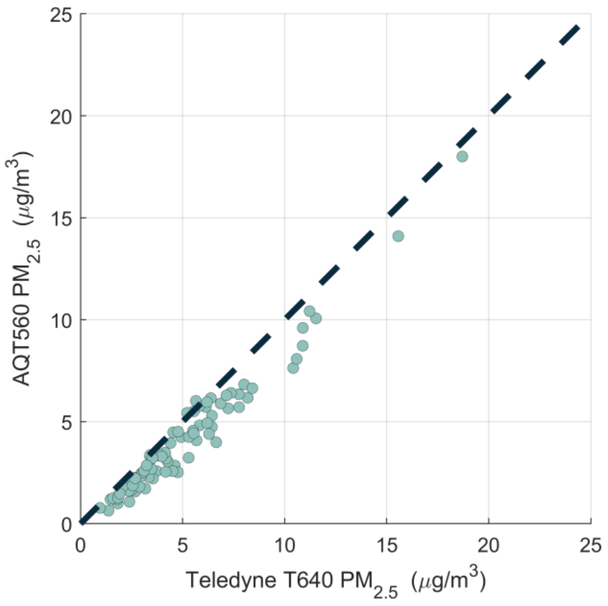
Mcert certificate

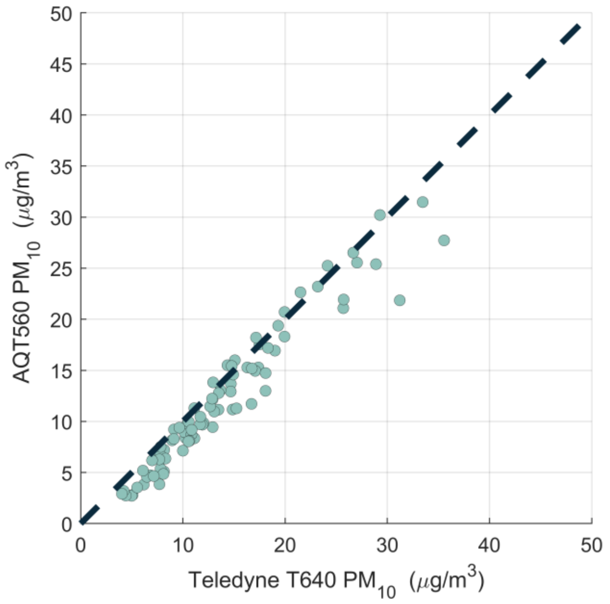
Ref.: Teledyne API T640 PM Mass Monitor in Albuquerque, New Mexico

24-h mean. 3 months of data



PM2.5

R^2 = 0.96
Slope = 0.91
MAE = 0.95
REU(at 20µg/m³) = 31.2%



PM10

R^2 = 0.94
Slope = 0.95
MAE = 1.87
REU(at 50µg/m³) = 20.9%

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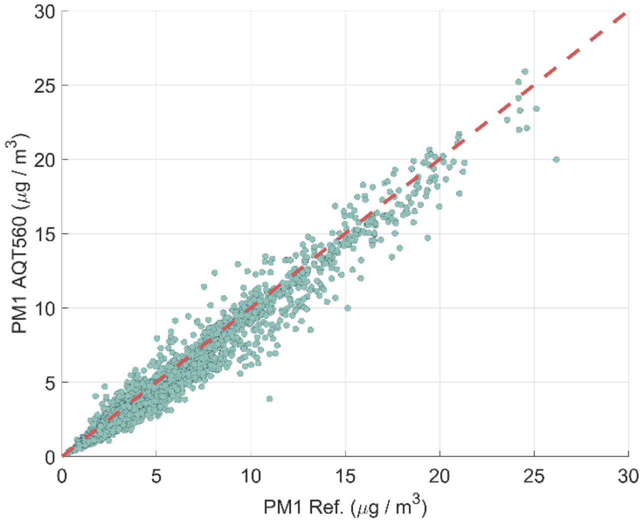
Strong correlation with optical reference

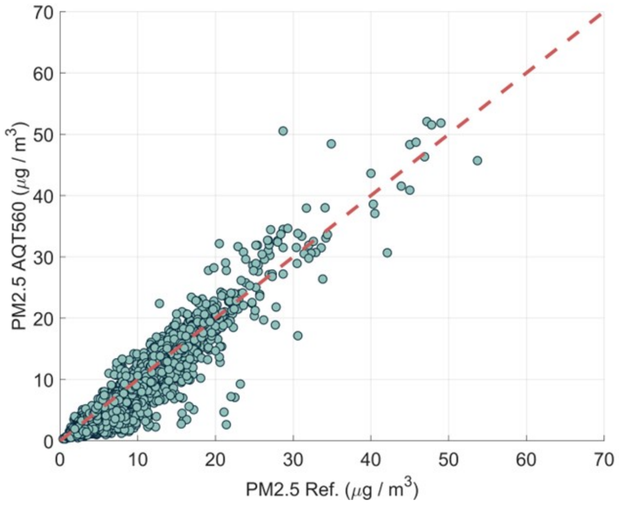
One-hour averages – Helsinki test site

PM1



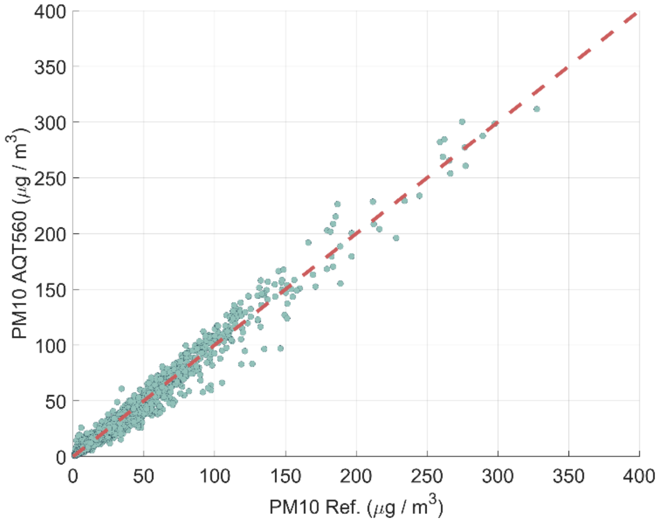
R^2 = 0.96
Slope = 0.96
MAE = 0.63
REU(at 50μg/m³) = 8.64%

PM2.5



R^2 = 0.9
Slope = 1.02
MAE = 1.44
REU(at 50μg/m³) = 6.32%

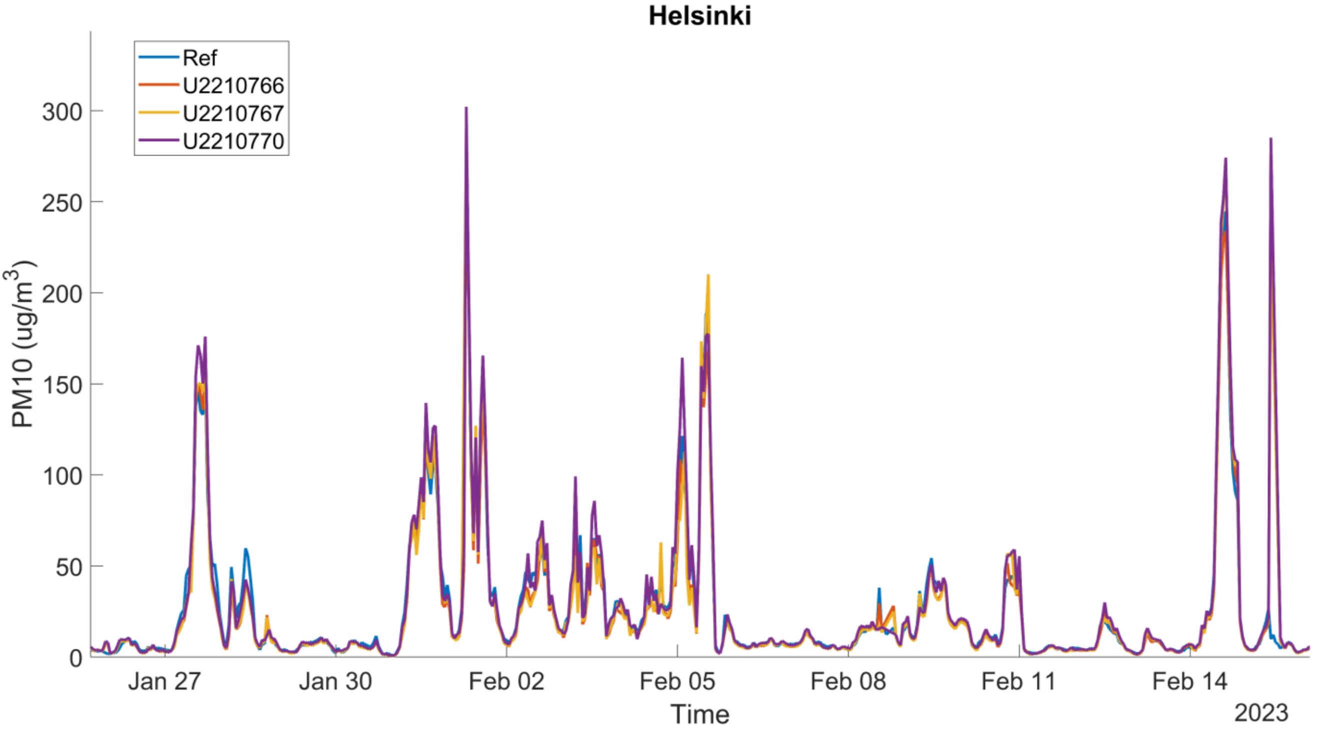
PM10

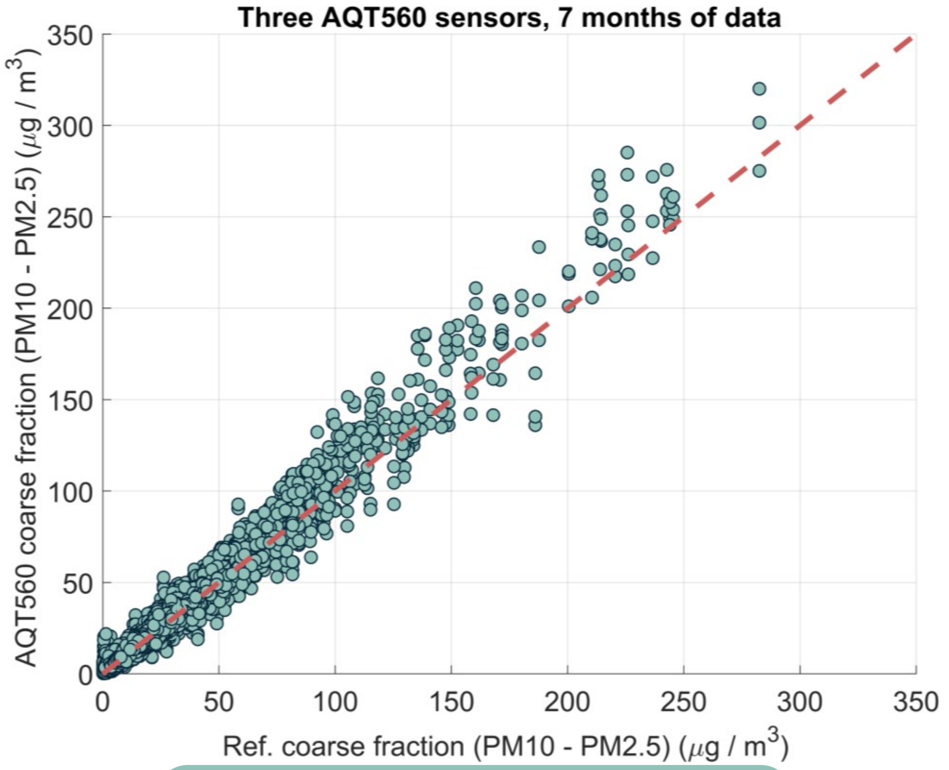


R^2 = 0.97
Slope = 1.0
MAE = 2.99
REU(at 50μg/m3) = 19.94%

Road dust and AQT560

Three AQT560 units and a reference during road dust season





R^2 = 0.97
Slope = 1.07
MAE = 2.67
REU(at 50µg/m³) = 22.86%

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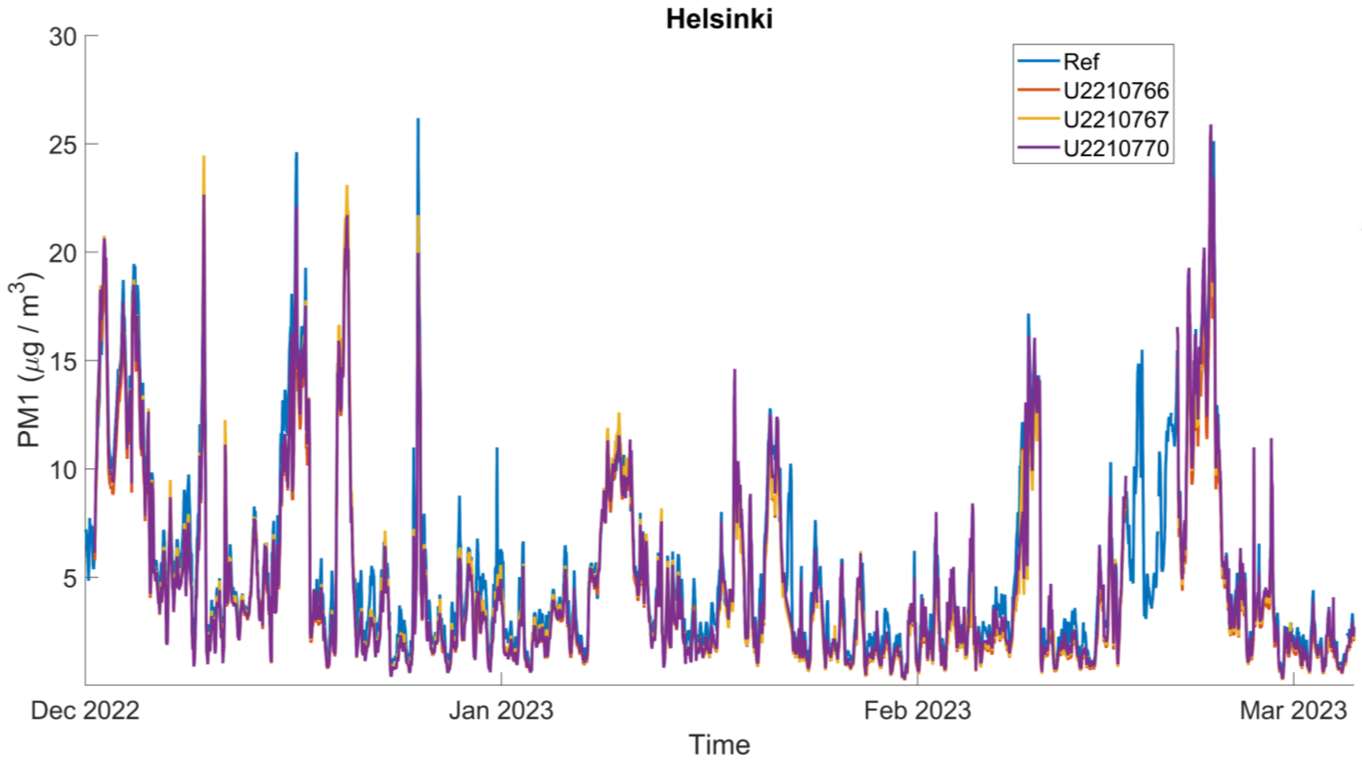
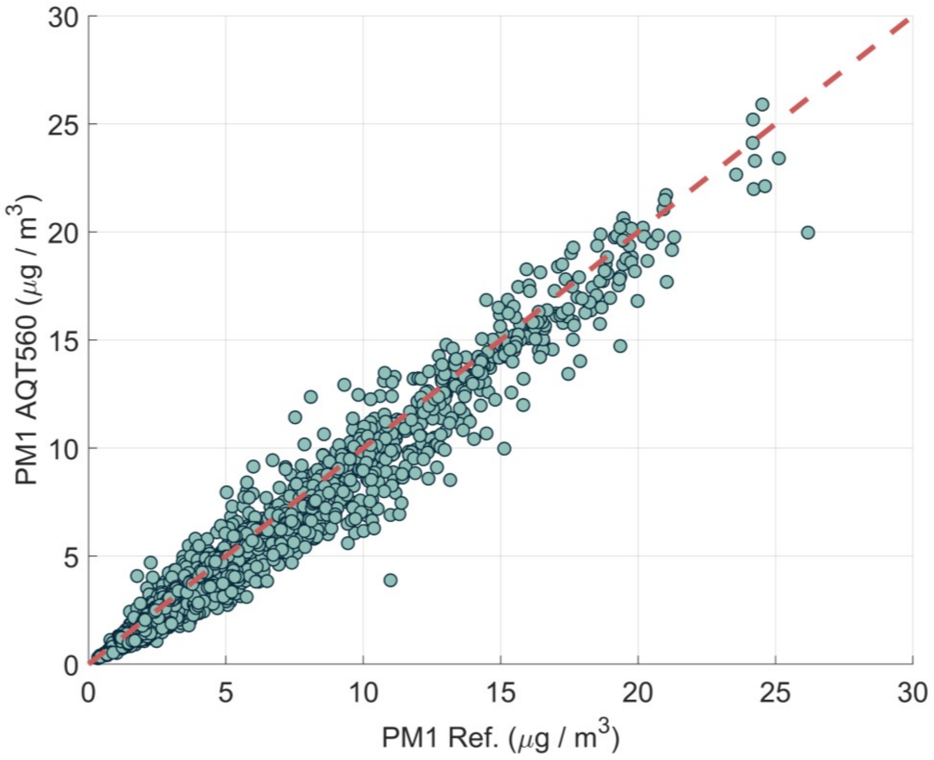
Residential wood burning in winter conditions

PM1 is elevated in winter months due to residential wood-burning





R^2 = 0.96
Slope = 0.96
MAE = 0.63
REU(at 50µg/m³) = 8.64%

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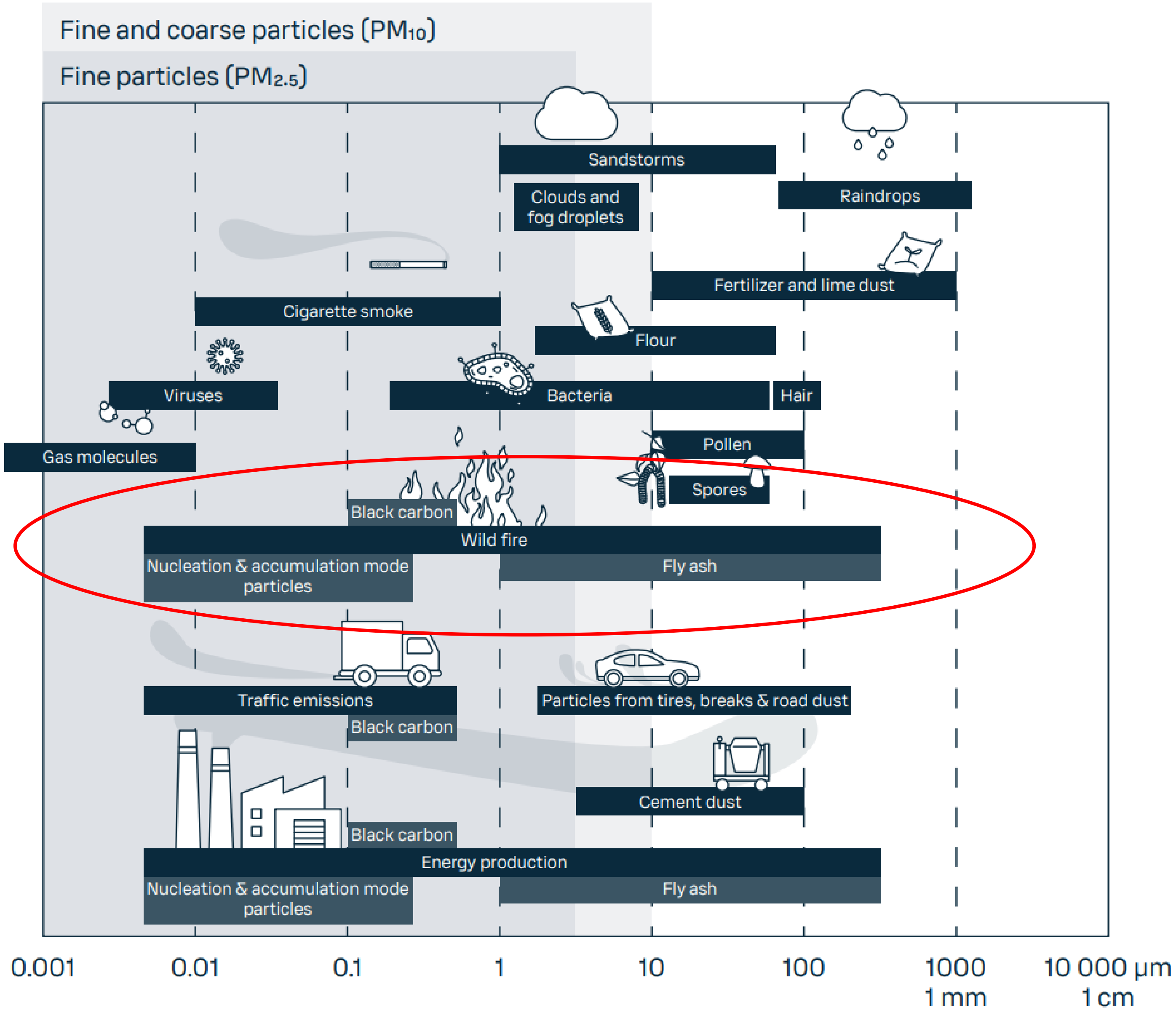
Forest fire detection with compact sensor

- Particle emissions: in 3 modes
  - Nucleation and accumulation mode particles
    - Very small when produced but grow fast to PM1 range
  - Black carbon
    - Remains challenging to optical sensors because it absorbs the light
    - Can be estimated based on NOx, CO and PM1 measurements
  - Reliable fly ash detection requires good coarse particle detection



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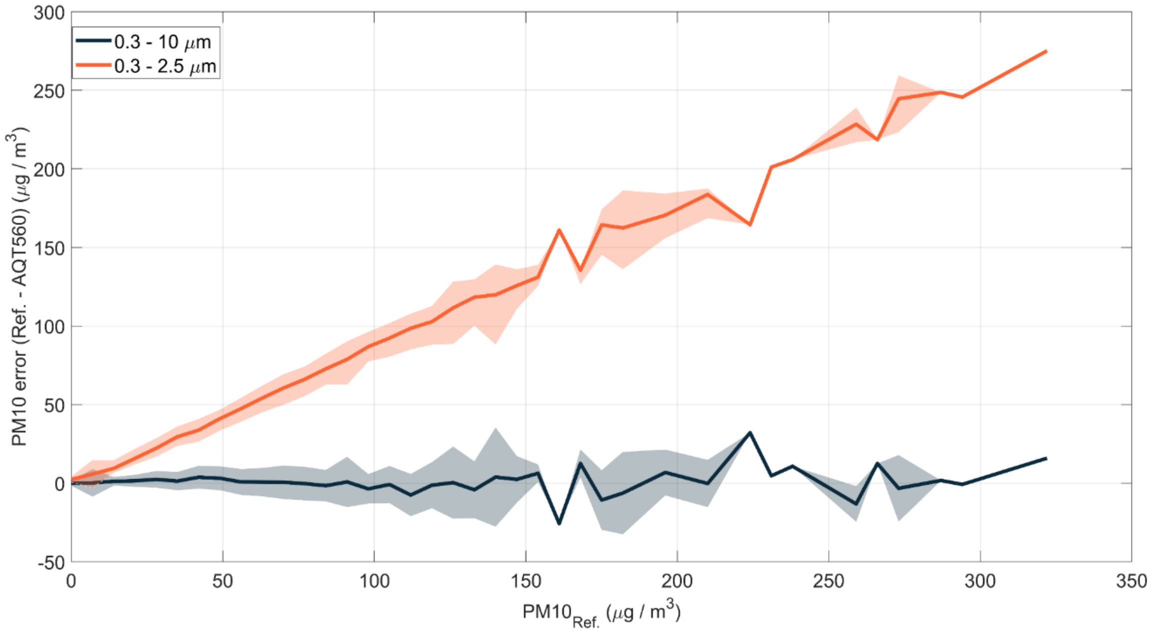
What if the detection range is limited?

PM10 example


Standard AQT560 unit

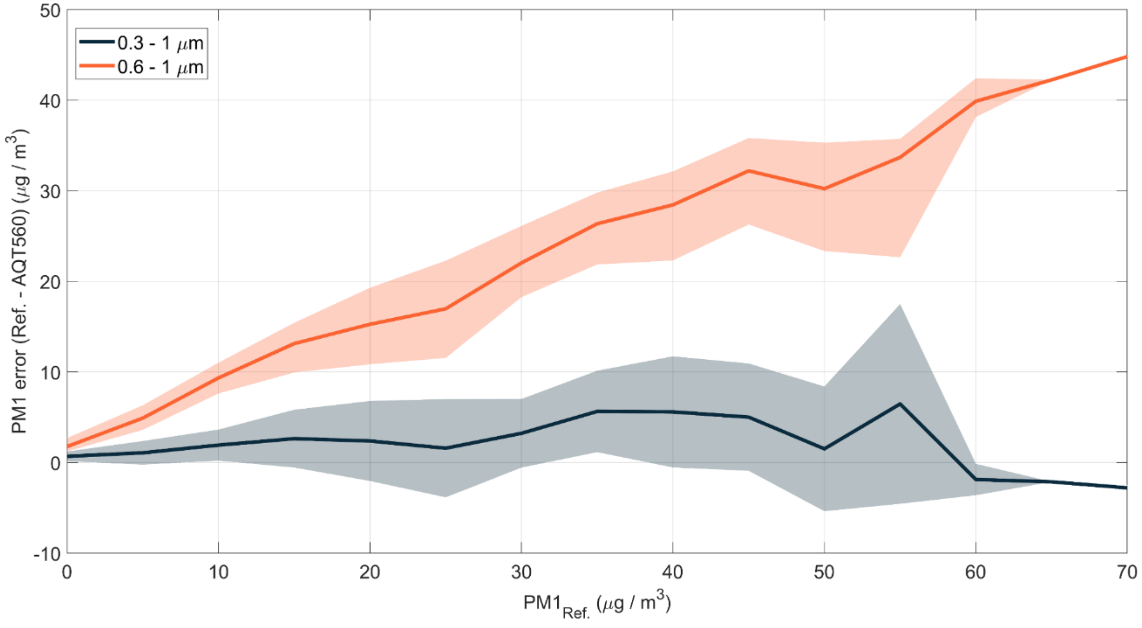

AQT560 unit with detection limited to 2.5 μm and smaller



PM1 example


Standard AQT560 unit


AQT560 unit with detection limited to 0.6 μm and larger particles



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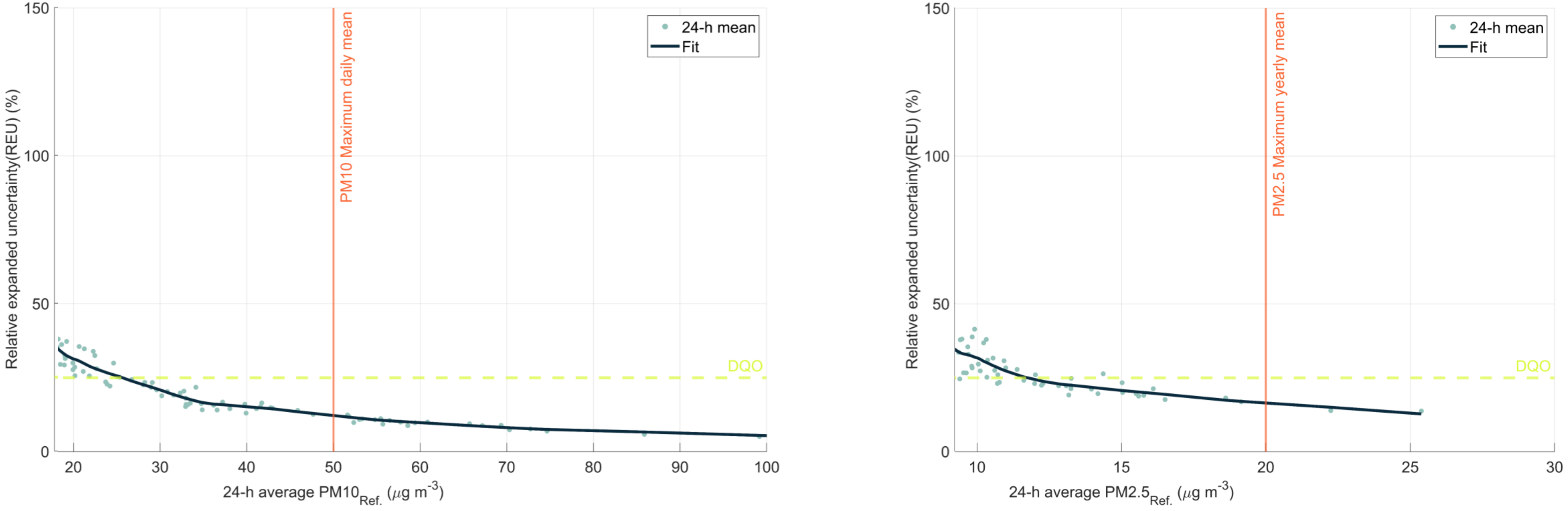
EU-legislation

EU limits for Relative Expanded Uncertainty **(REU) of < 25%** for reference equivalence methods at

- Daily limit **(50 µg / m3) for PM10** can be exceeded max 35 times in a year
- Annual average limit **(30 µg / m3) for PM2.5**

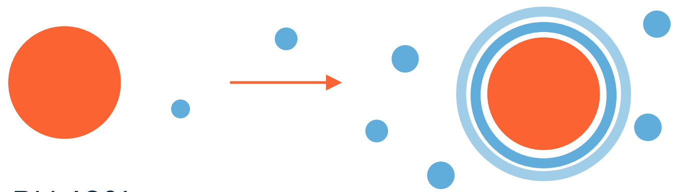


AQT560 is fulfilling indicative class requirements (even without co-location correction) and is close to the reference equivalent class

Minimizing humidity dependency

Hygroscopic growth is an issue with compact sensors since they don't have dryers

Particles gain water and grow in humid conditions



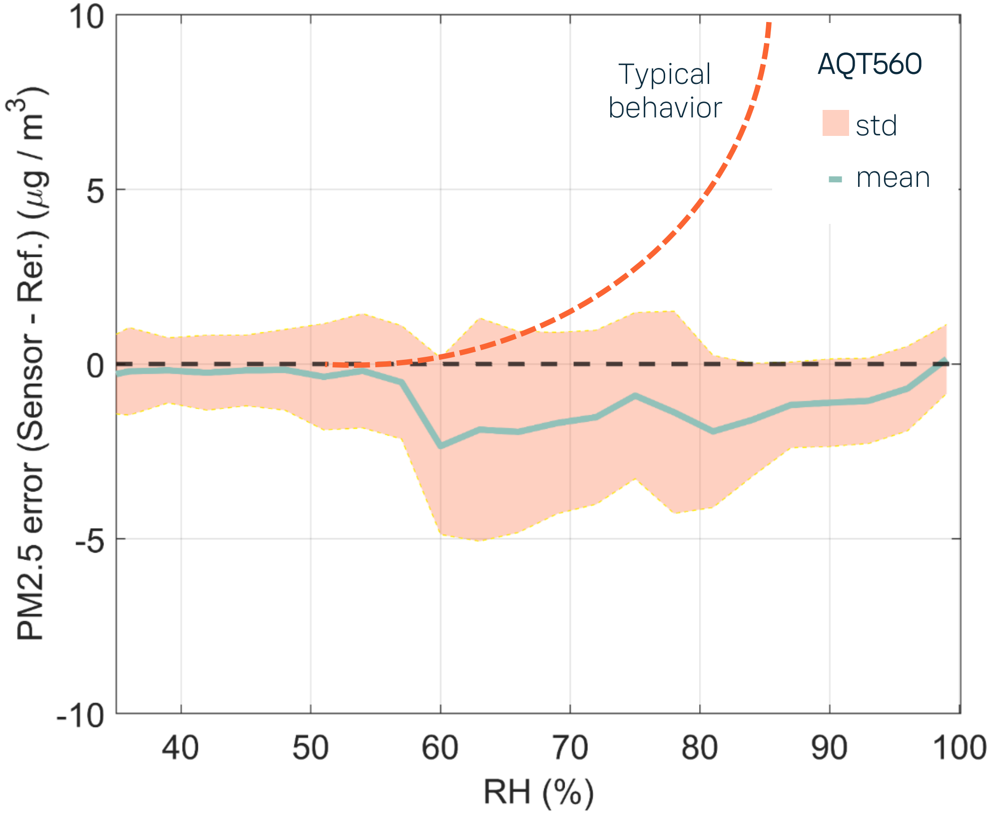
but AQT560 measures:

Humidity and temperature

Particle sizes

+ Smart algorithms

AQT560 coping well with humidity



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Fog conditions saturate optical sensor measurement, and in that case the data is flagged

Conclusions

- AQT560 performs solid against multiple reference equivalence methods
- Coarse particles are accurately measured which enables monitoring where these are a dominant/important factor
- Small particle emissions from fires are reliably detected
- Smart algorithms compensate and mitigate dependencies for high relative humidity
- Accurate measurements without co-location corrections or post processing

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