Is PM sensor testing really testing the sensors?

Experiences from 400 days of field tests in the Life VAQUUMS project

Jordy Vercauteren

VLAAMSE MILIEUMAATSCHAPPIJ

VAQUUMS

Table 1:PM-sensors that started the Vaquums field campaign.

Honeywell **HPMA** 115S0	**Dylos** DC1700	Nova Fitness **SDS**011
Plantower PMS7003	**Winsen** ZH03B	Shinyei **PPD**60PV
(Shinyei PPD42NS)	*(Alphasense OPC-N2)*	

- Urban background Antwerp (Belgium)
- 401 days (Feb 2019-Mar 2020)
- 6 sensor types x 5 units/type
- 2 reference systems
- No external algorithms (e.g. RH)

EU gravimetric reference ($PM_{2.5}$ only)

EU equivalent method (Palas Fidas 200)

What did we look at?

- 5min, 1h and 24h data. Focus on 1h data
- $PM_{2.5}$, PM_{10} and also PMcoarse !
- Comparison with ref. monitor (R^2, scatterplots,mean bias)
- Between sensor uncertainty (sd, rsd)
- Uncertainty at the limit value vs 24h gravimetric ref (official EU method)
- 'humidity factor'
- Need for manual validation/data coverage

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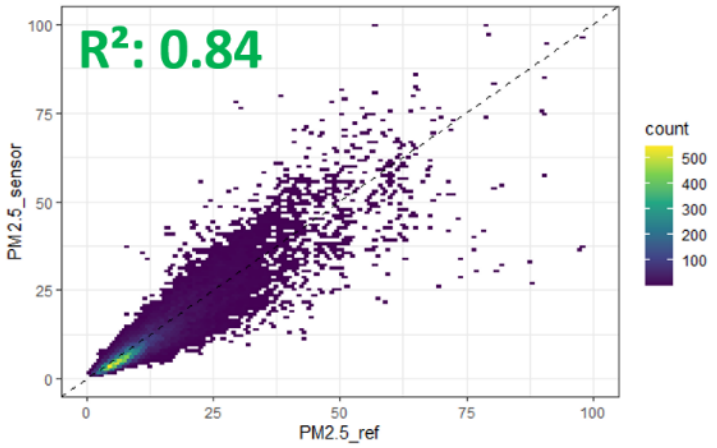
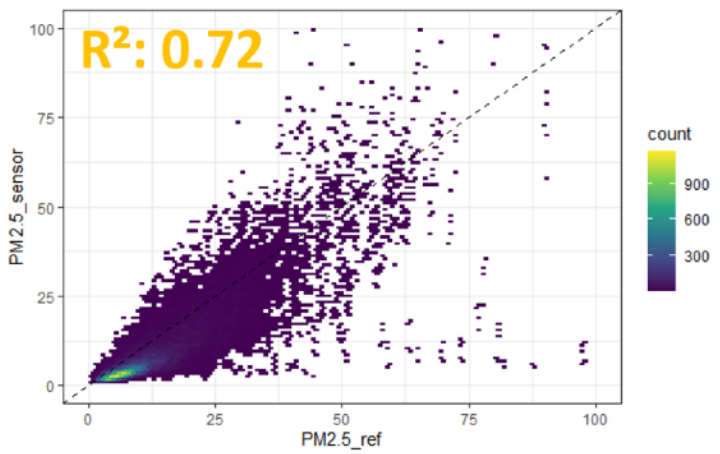
$PM_{2.5}$ correlations (sensor vs Fidas)

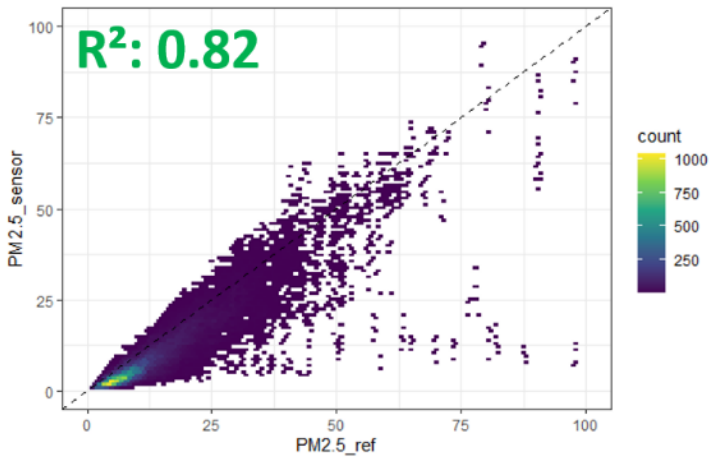
HPMA



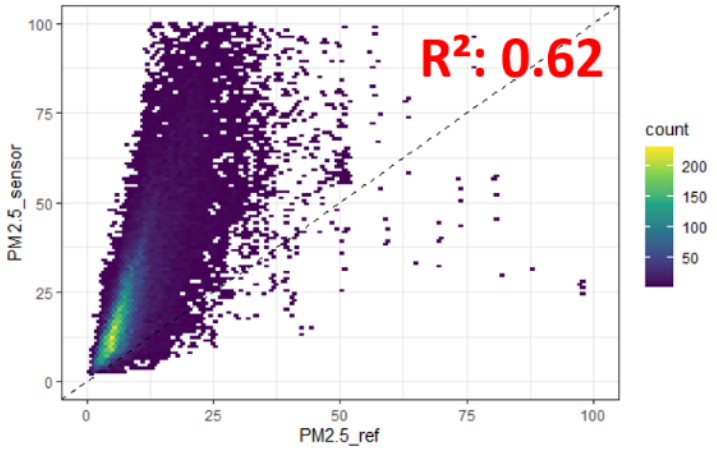
SDS



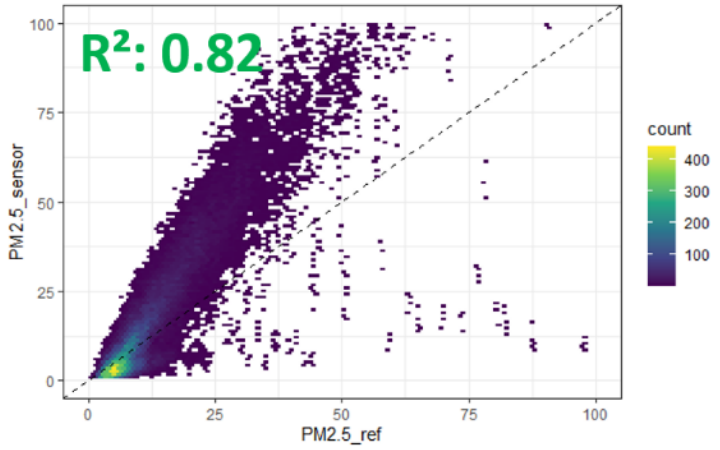
Winsen



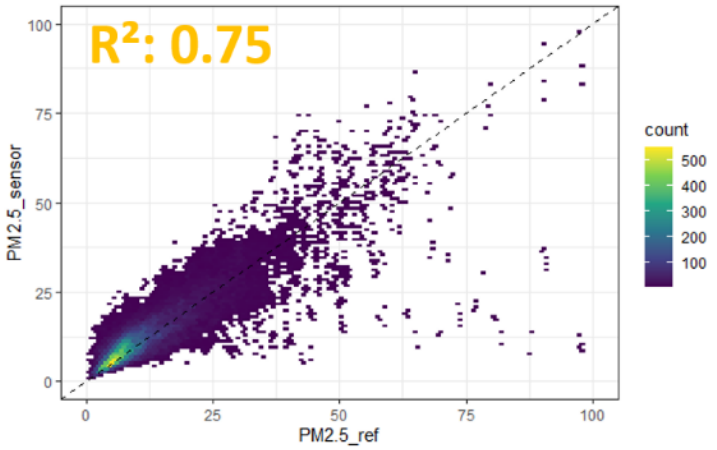
Dylos



Plantower



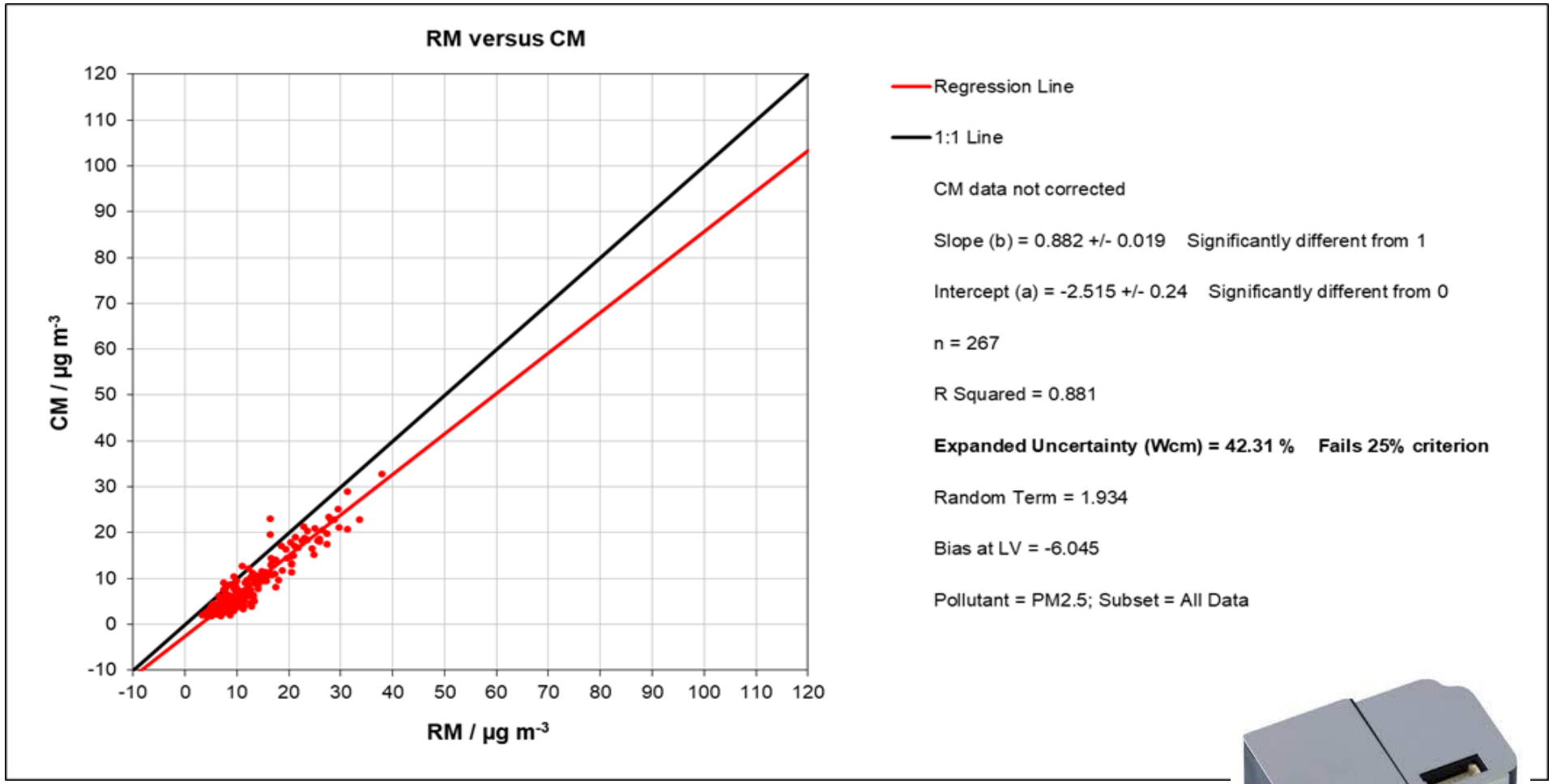
PPD60pv



EU demonstration of equivalence (vs 24h grav. ref.)

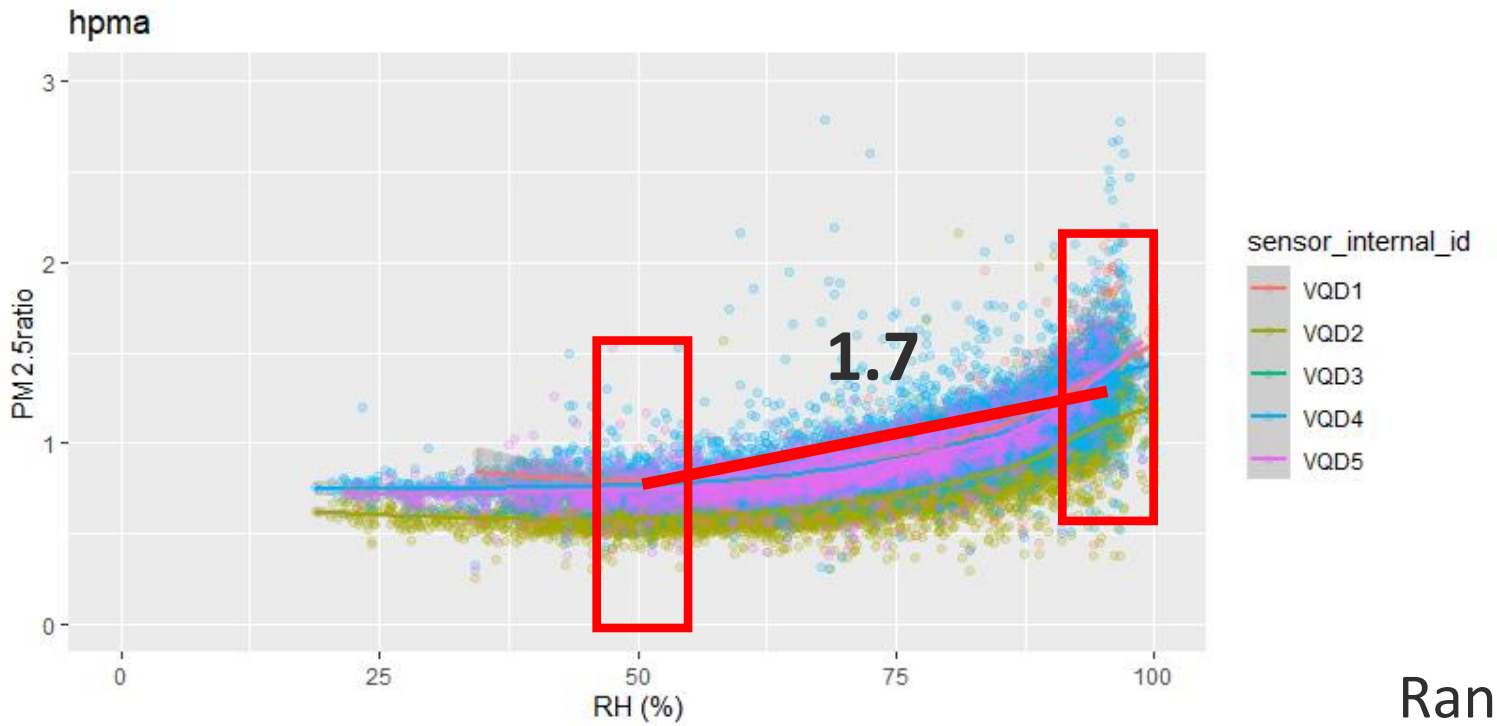
"24h average of all valid data"

Unc. = random term & bias at limit value (minus ref. uncertainty)



“humidity factor”:

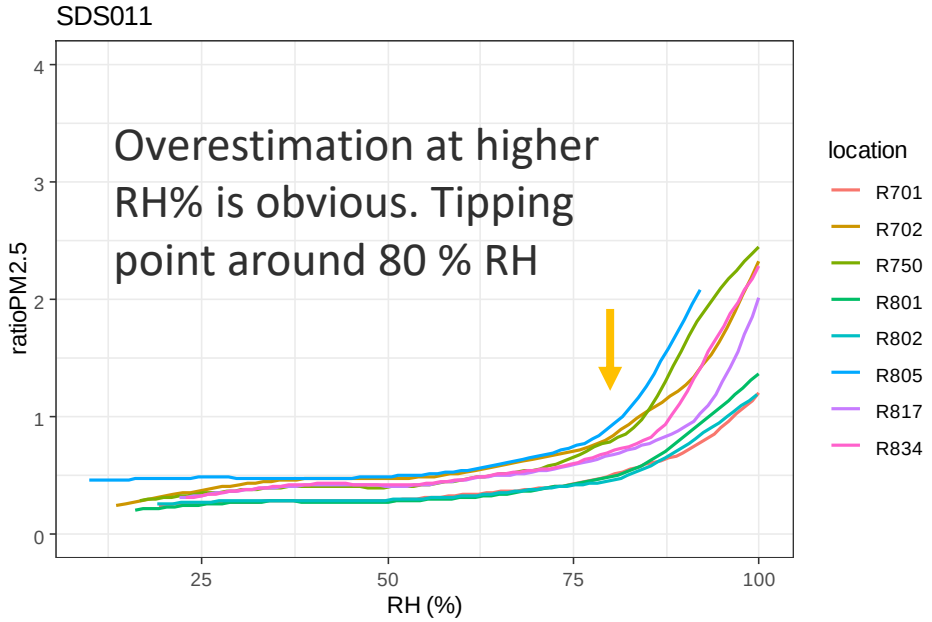
$PM_{2.5}$ sensor/ref. above 90% vs around 50% (ratio of 2 ratios)

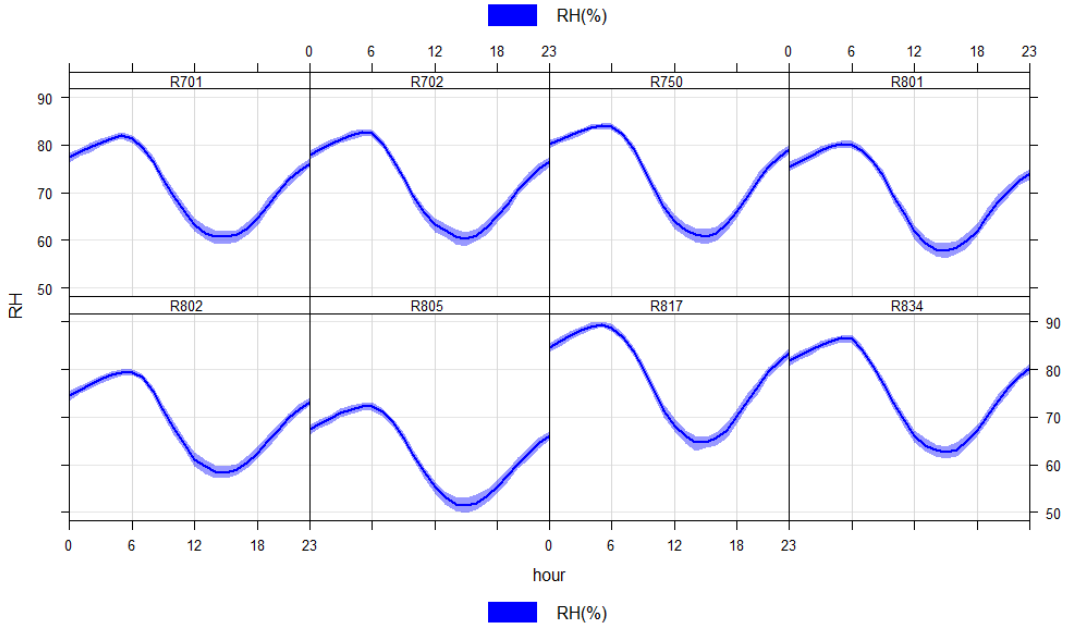


Range for different sensor types:
1.4 <-> 2.4

“Testing the sensor …and the aerosol+RH at your site”

Humidity effect at 8 sites (SDS-011 only)





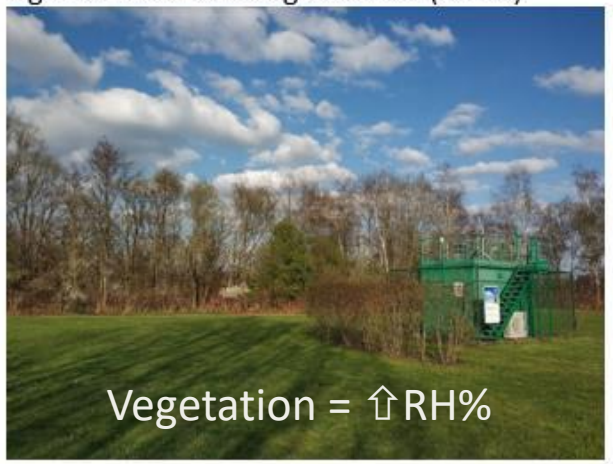
Underestimation during the day (partially) compensated by **overestimation** at night

> results **better for 24h** data

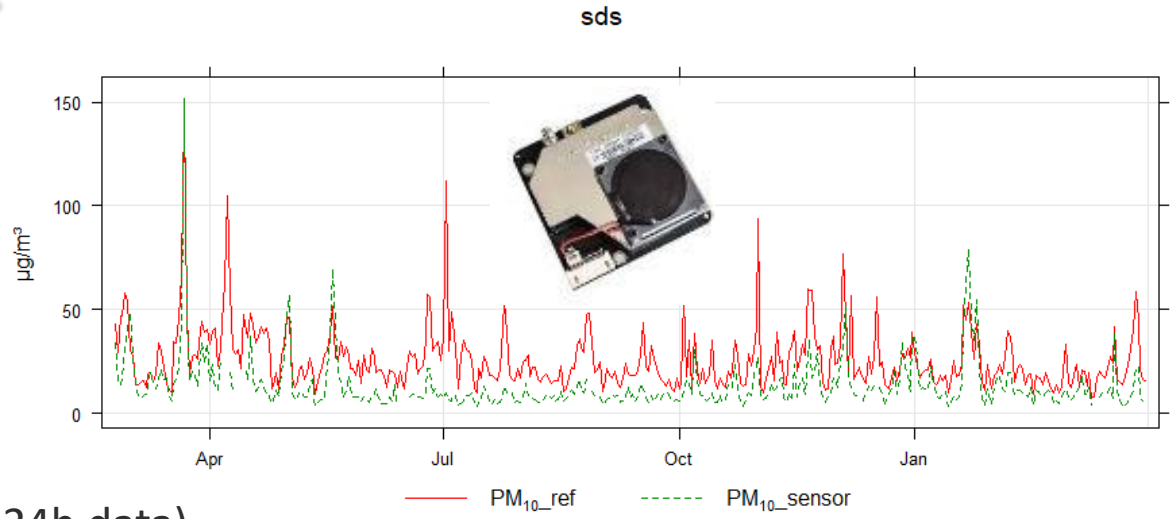
> **location** effect !

(influence of RH larger at sites with more vegetation)

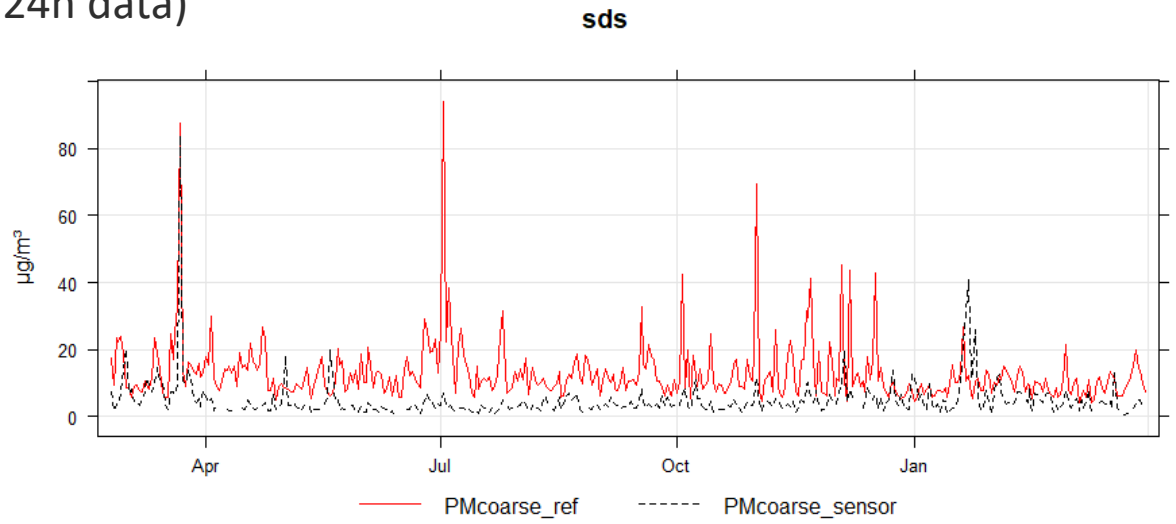
Figure 132: Monitoring site R834 (Boom)

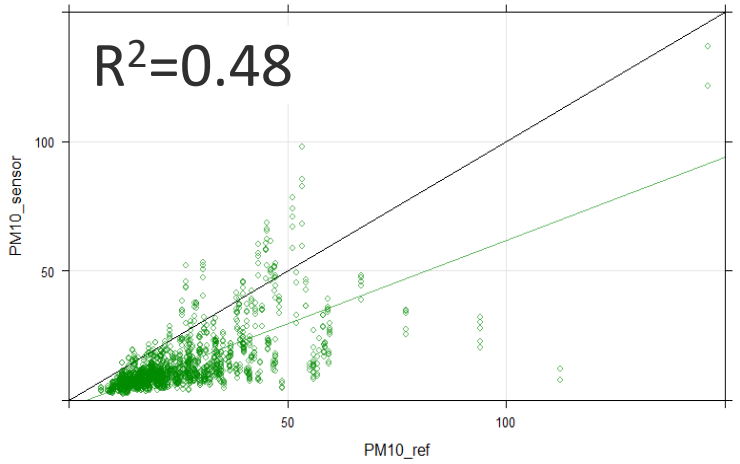


$PM_{10} = PM_{2.5} + PM_{coarse}$

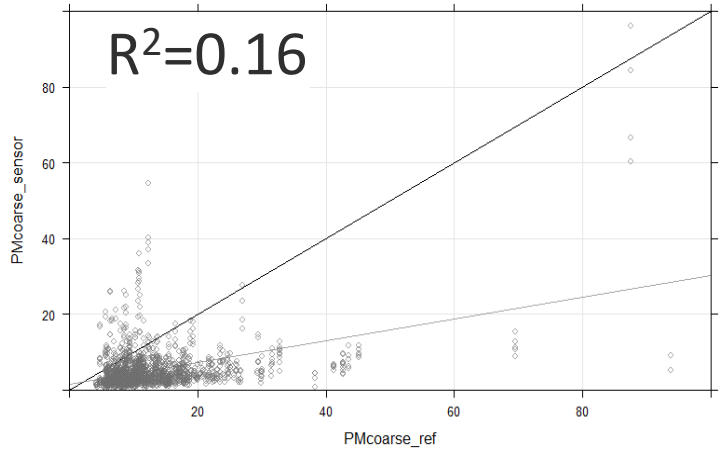


(24h data)





PM_{10}



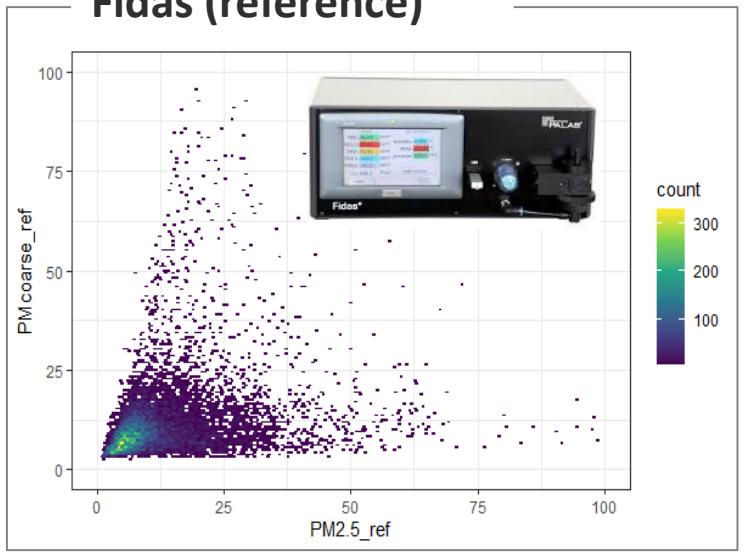
PM_{coarse}

Bad results for all sensors.
Only SDS011 and Dylos appear to pick up some particles >2.5 µm

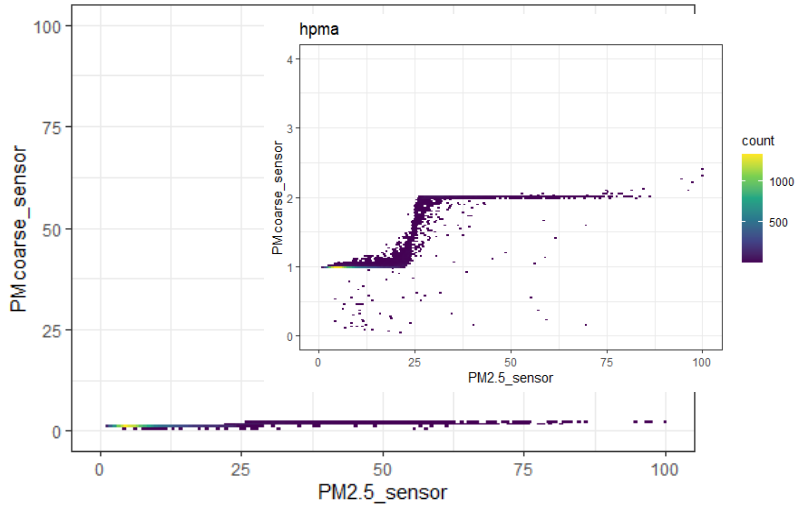
Is it a true PM_{10} sensor? **>> look at PM_{coarse}**

sensor PM_{coarse} vs sensor $PM_{2.5}$

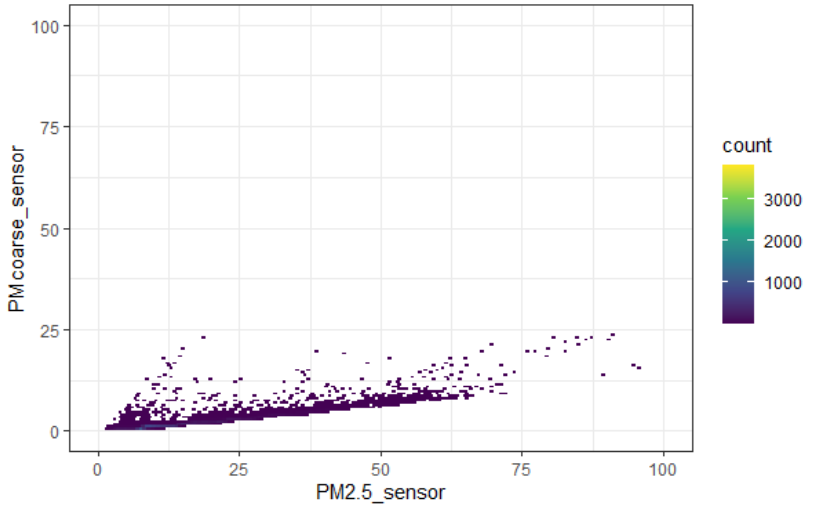
Fidas (reference)



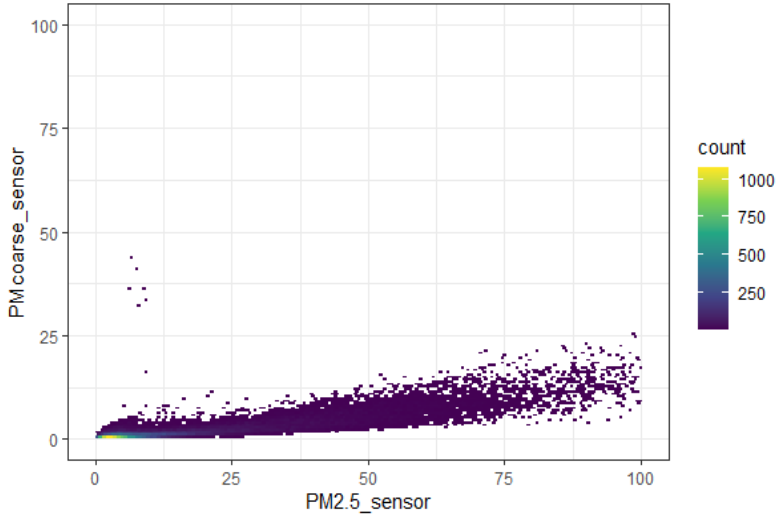
HPMA



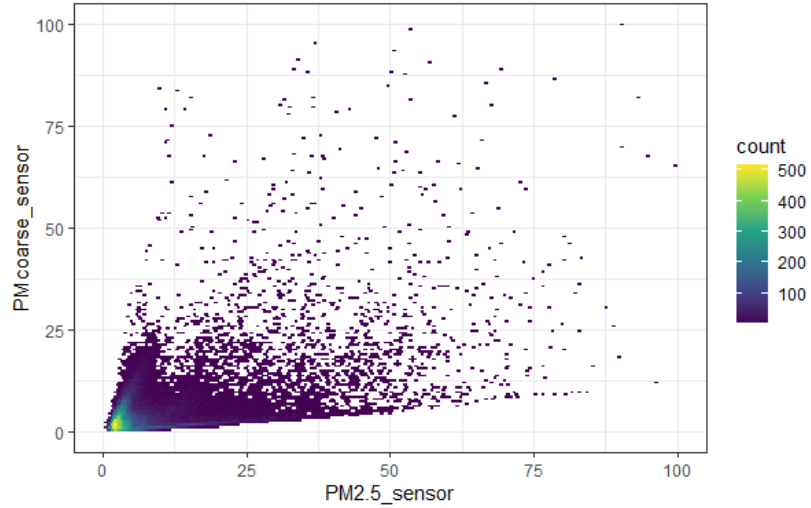
Winsen



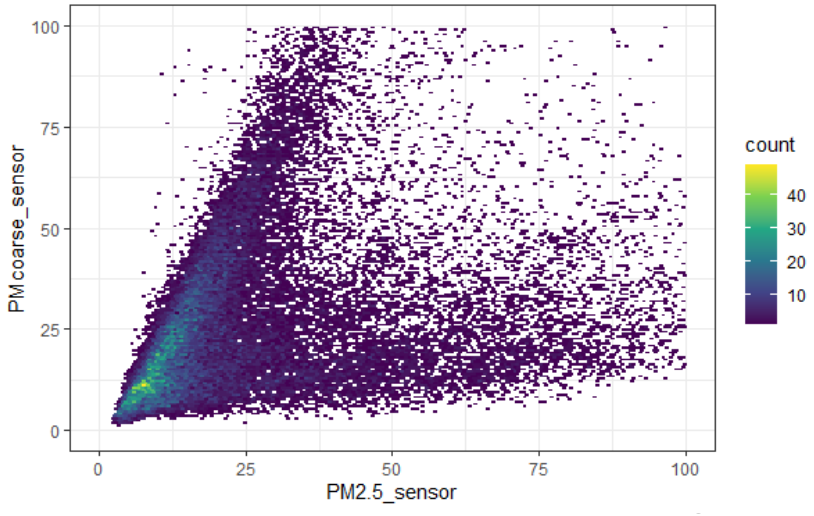
Plantower



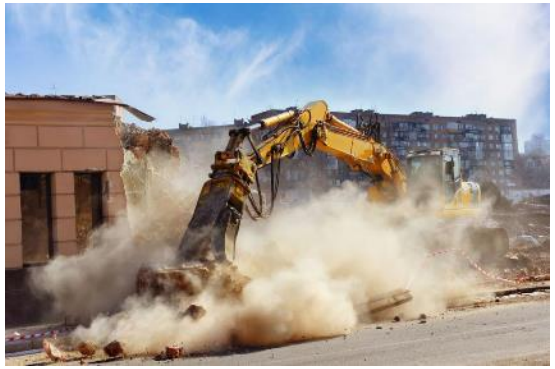
SDS



Dylos



Be aware : Local PM can often be PM_{coarse}



(de)construction works

resuspension,
break and tire ware

Industrial handling,
transshipment

But (local) combustion = $PM_{2.5}$

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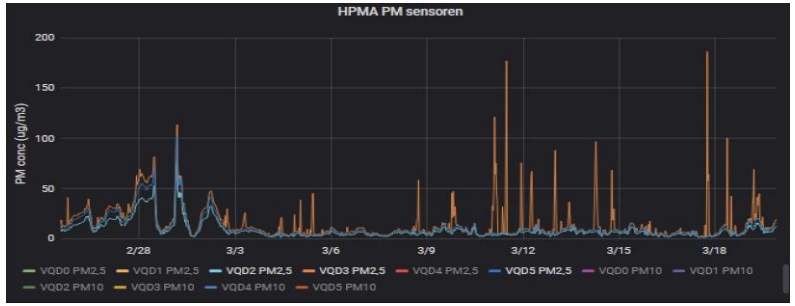
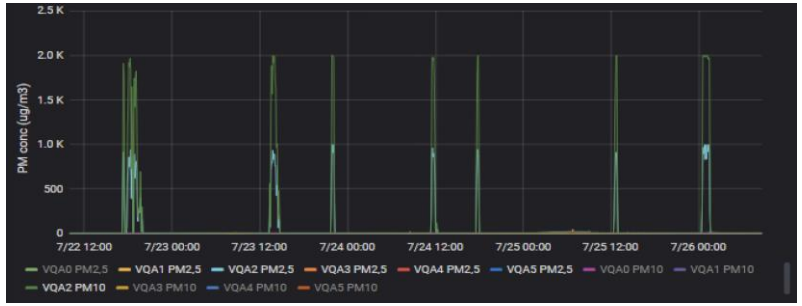
Manual validation matters

Vlaanderen is milieu

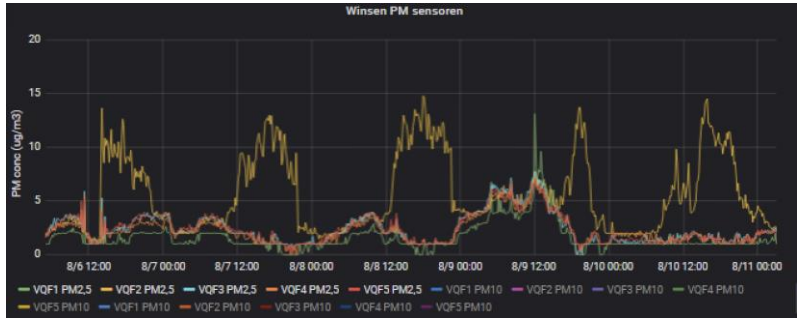
Short spikes



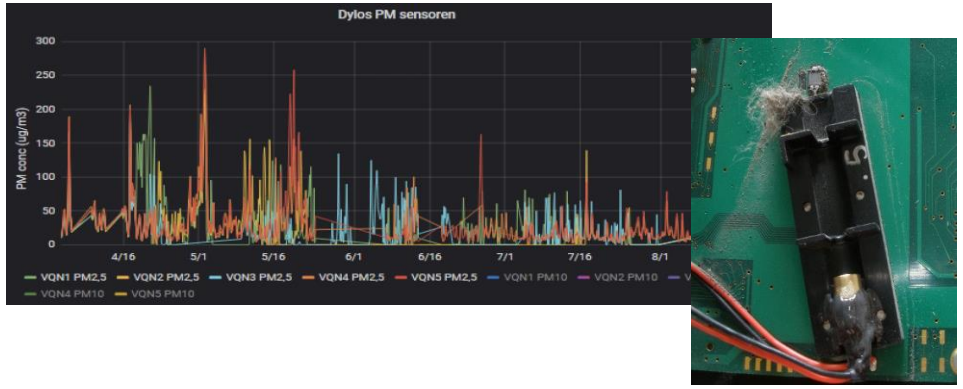
Max values



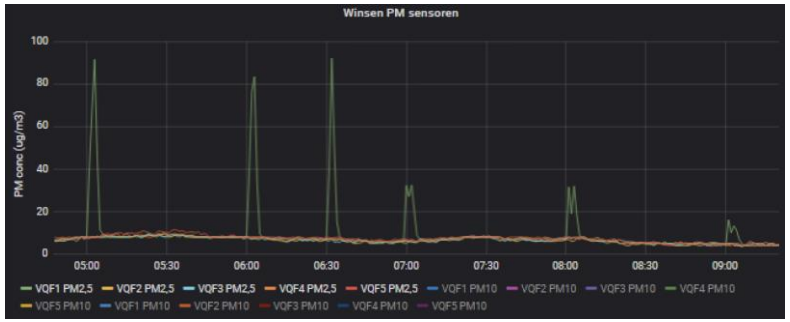
Light/heat interferences (?)



‘all over the place’ data



Electronic interferences (?)



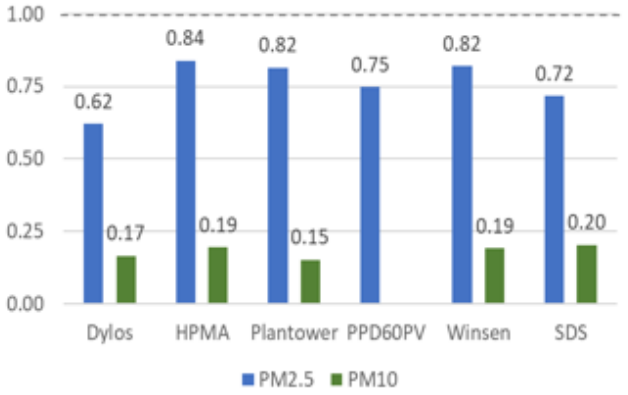
PM-sensors

Tested PM-sensors

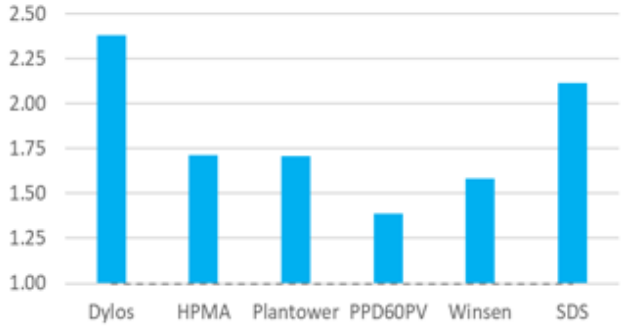
- Dylos DC1700
- Honeywell HPMA 115S0
- Plantower PMS7003
- Shinyei PPD60PV
- Winsen ZH03B
- Nova Fitness SDS011
- *Shinyei PPD42NS**
- *Alphasense OPC-N2**

*excluded from test due to technical problems

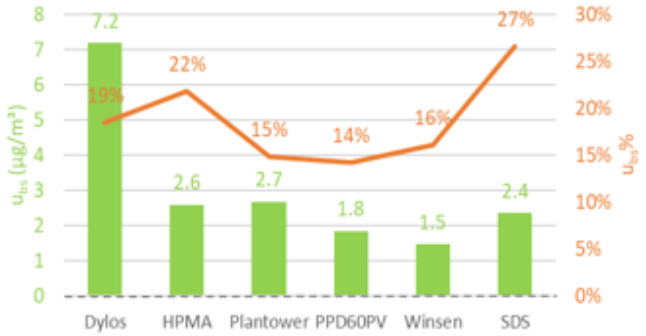
R^2 of hourly sensor data vs Fidas 200



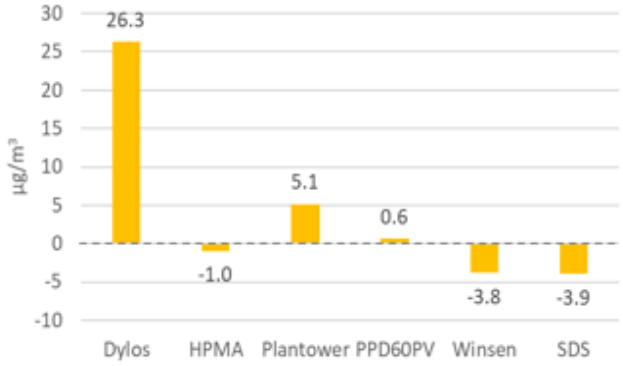
Increase in $PM_{2.5}$ sensor/Fidas ratio from 50% to +90% relative humidity



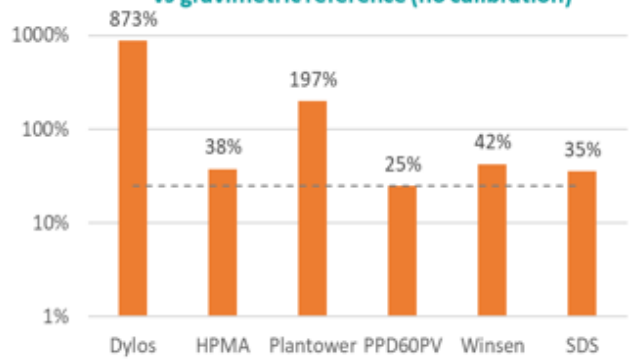
Between-sensor uncertainty for hourly $PM_{2.5}$ data (u_{bs})



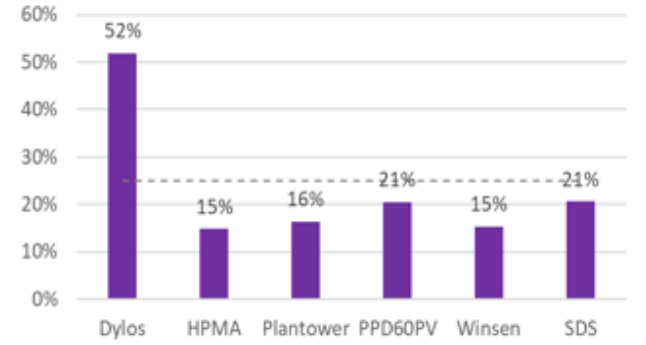
Mean bias of hourly $PM_{2.5}$ sensor data vs Fidas 200



Expanded uncertainty of 24h $PM_{2.5}$ sensor data vs gravimetric reference (no calibration)



Expanded uncertainty of 24h $PM_{2.5}$ sensor data vs gravimetric reference (after calibration)

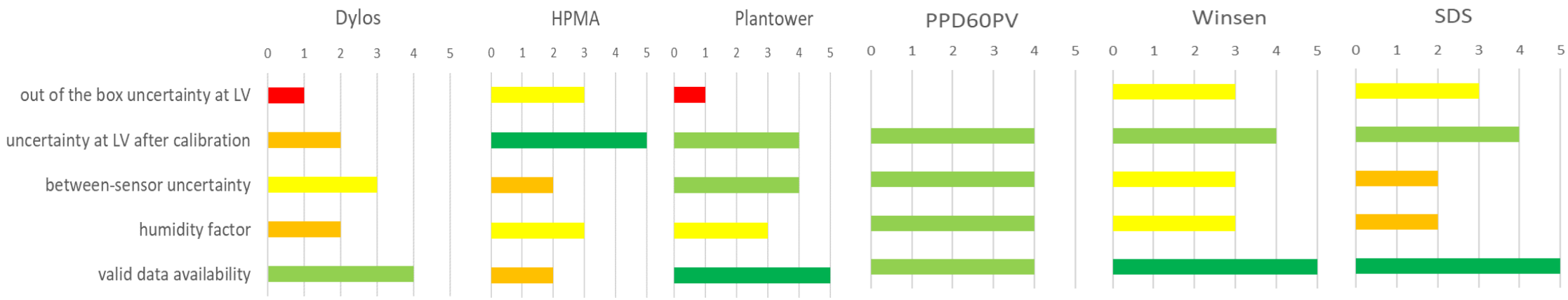


FIELD TEST FACT SHEET

Setup and definitions see: Vaquums test protocol - Full test report see: Vaquums PM fieldtest report

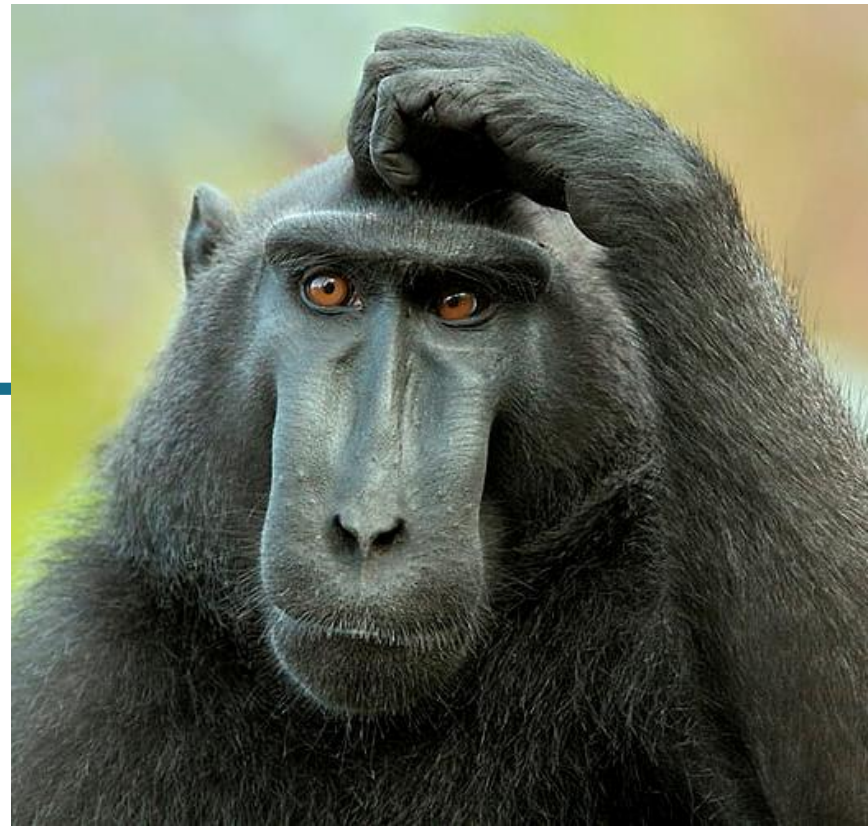
Sensor quality index

	5 excellent	4 good	3 ok	2 poor	1 bad
out of the box uncertainty at LV (%)	<15	<25	<50	<100	>100
uncertainty at LV after calibration (%)	<15	<25	<50	<100	>100
between-sensor uncertainty (%)	<10	<15	<20	<30	>30
humidity factor	<1.25	<1.5	<2	<3	>3
data availability (#valid hours)	>35000	>30000	>25000	>20000	<20000



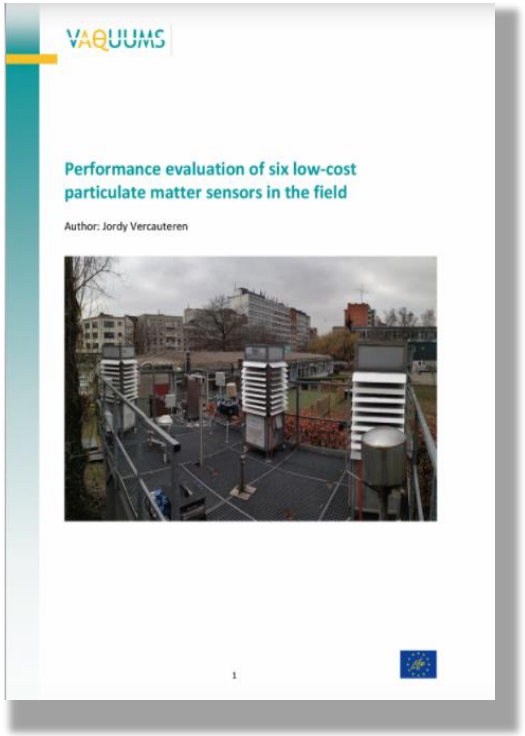
Are we really testing the sensors?

- Or are we testing the specific conditions of the test?
- Or are we also testing our validation skills?



- Are we only testing the average performance?
- Shouldn't we focus more on the extremes (best/worst)?
- Shouldn't we test specific aerosol (e.g. PMcoarse)

(regional/secondary PM is already covered by the AQ-networks)



https://**vaquums.eu**/sensor-db/tests

j.vercauteren@vmm.be

https://github.com/EvelyneElst/LIFE_VAQUUMS
(full dataset)