

# More Fireworks Less Pollution?

# LV2



Foto: website Suriname Herald

---

Lucht voor Leidschendam-Voorburg

Frans Kets

# More Fireworks, less pollution?

## Agenda

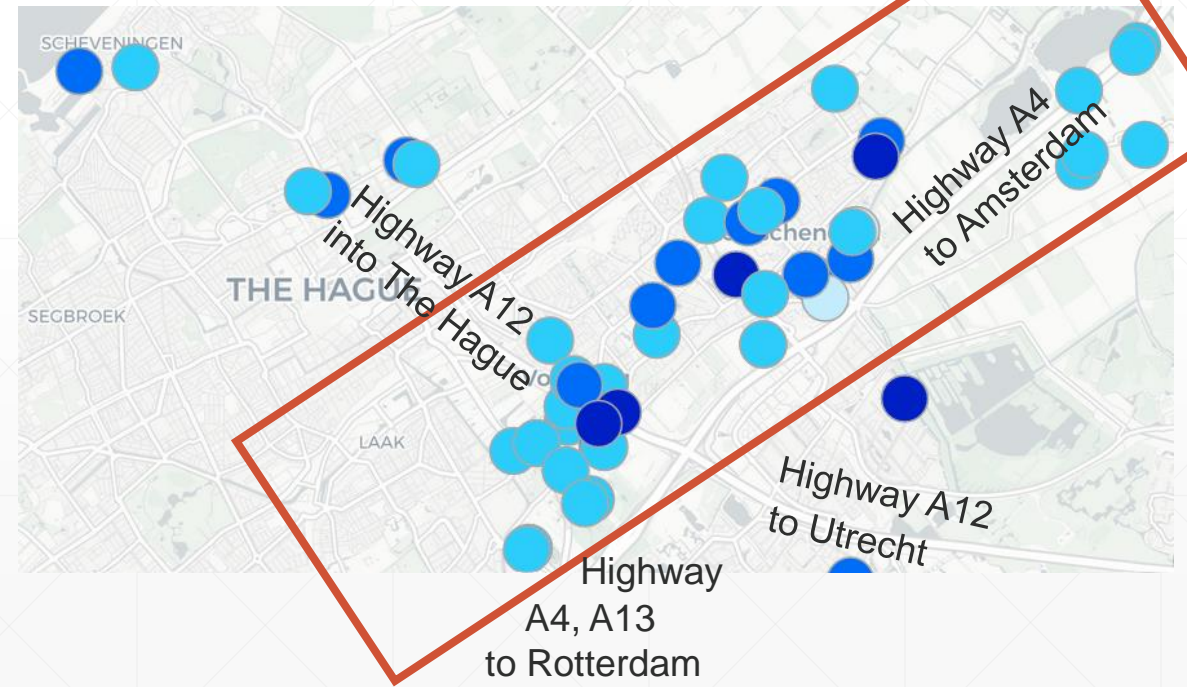
- Introductory remarks
  - Recognizing the Corona effect
  - Comparison of firework signatures over the years
  - Are the measurements valid?
  - Conclusions
-

# LV2

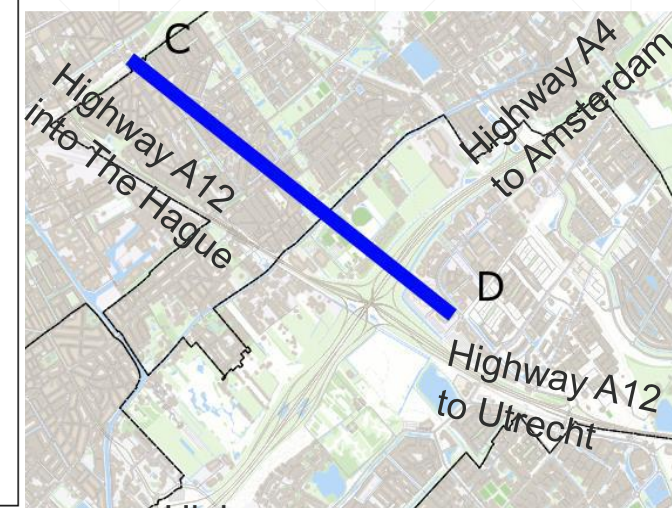
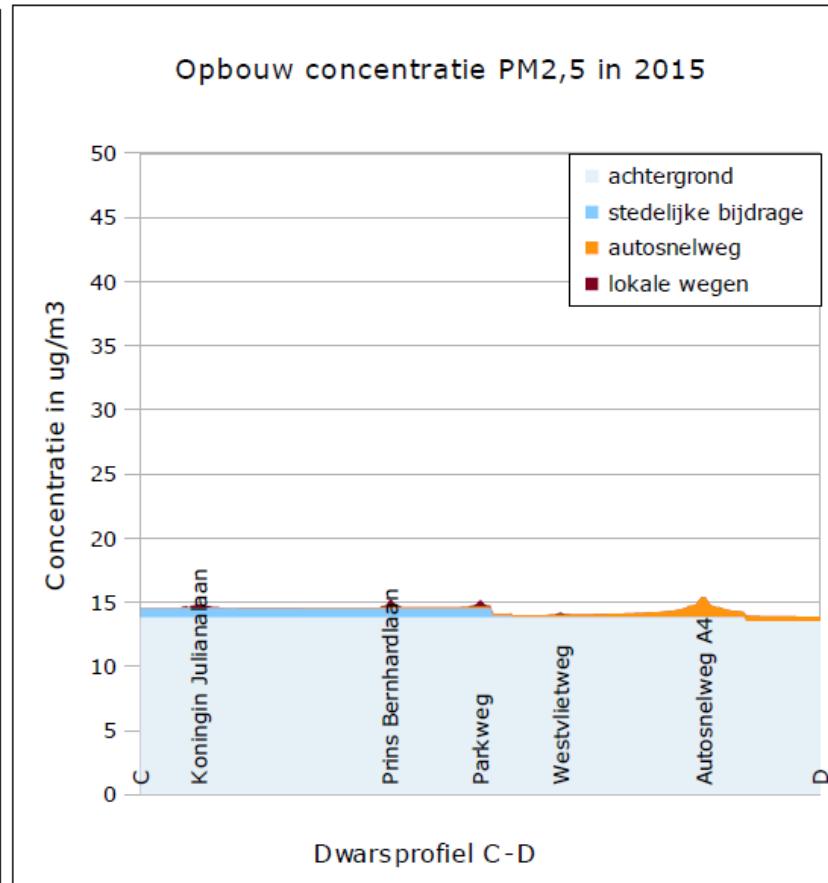
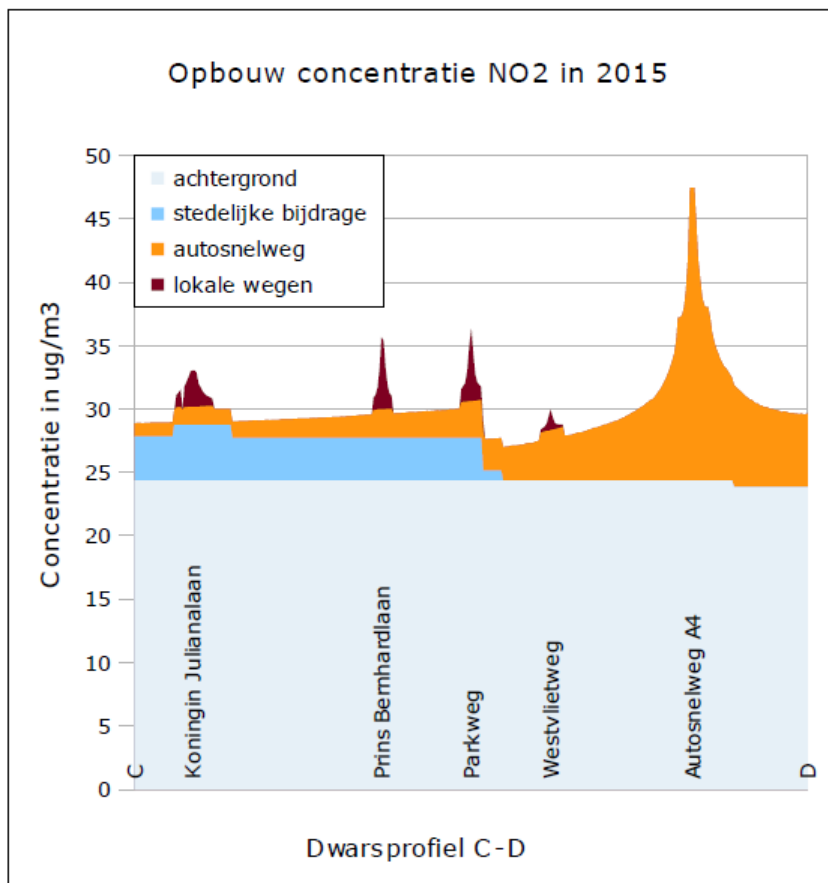
## Lucht Voor Leidschendam-Voorburg

- Objective:
  - *Health improvement in Leidschendam-Voorburg by improving airquality*
- Aim measurements:
  - Actionable measurements
  - Recommendations for action
- Locate and quantify sources
- Measurements
  - What do we measure?
  - How does the measurement relate to the source(s) ?

### Leidschendam-Voorburg “Suburb” of The Hague



# Cross-section Voorburg Official Knowledge 2015

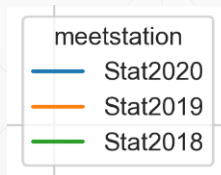


Highway  
A4, A13 to Rotterdam

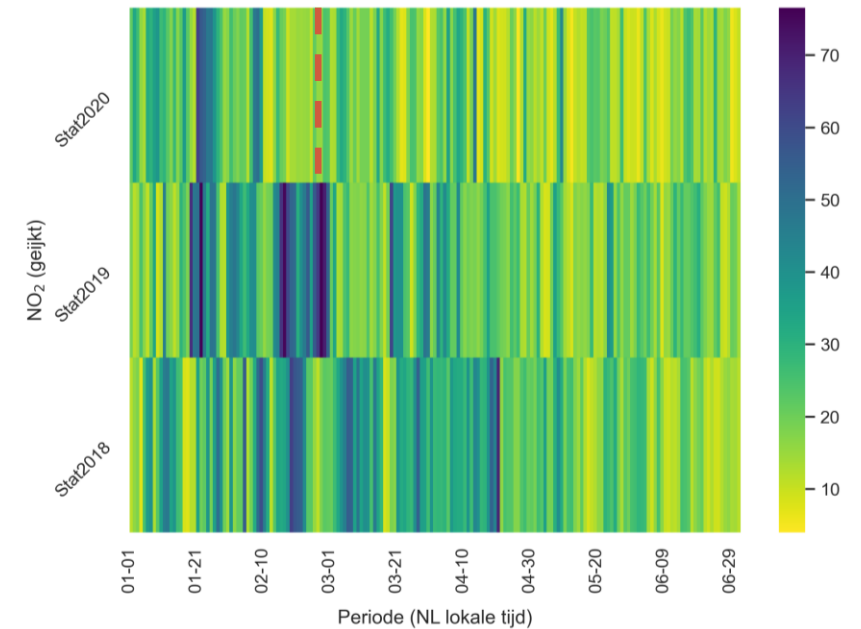
# Exercise 2020: Can we observe Corona lockdown effects in our measurements?

*Comparison of 2018, 2019, 2020 NO<sub>2</sub> data from 3 RIVM stations in The Hague*

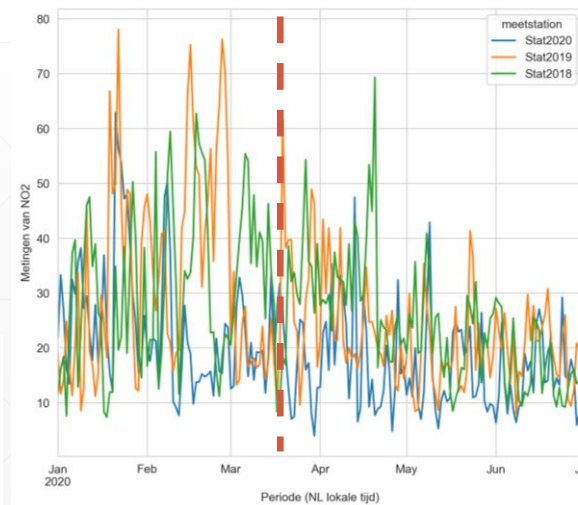
- *Lockdown date was 15 March.  
No significant change at that date*
- Weather effect dominates the response



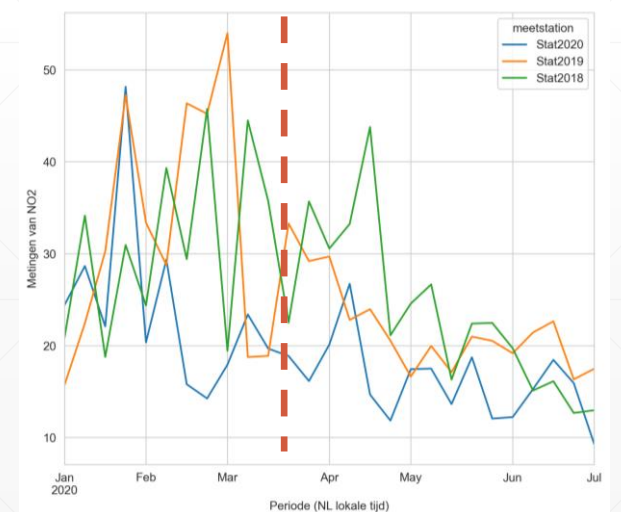
NO<sub>2</sub> (geijkt) (per dag) metingen versus tijd



NO<sub>2</sub> (geijkt) Meetwaarden (per dag) - gemeten bij de stations



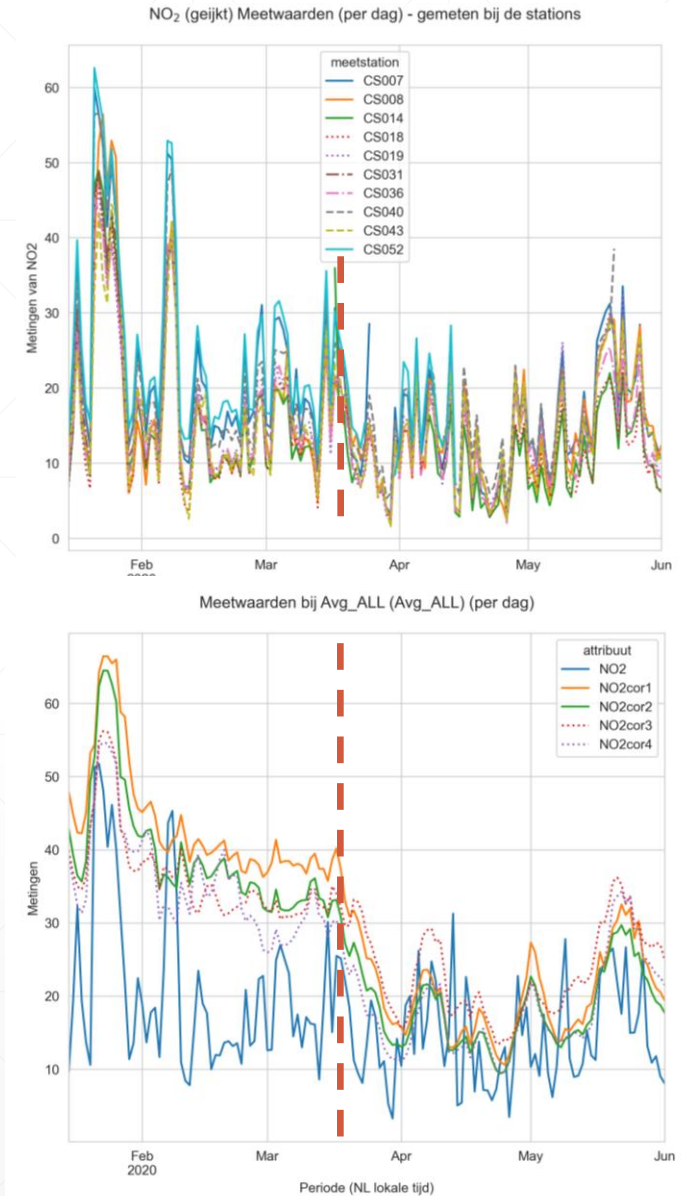
NO<sub>2</sub> (geijkt) Meetwaarden (per week) - gemeten bij de stations



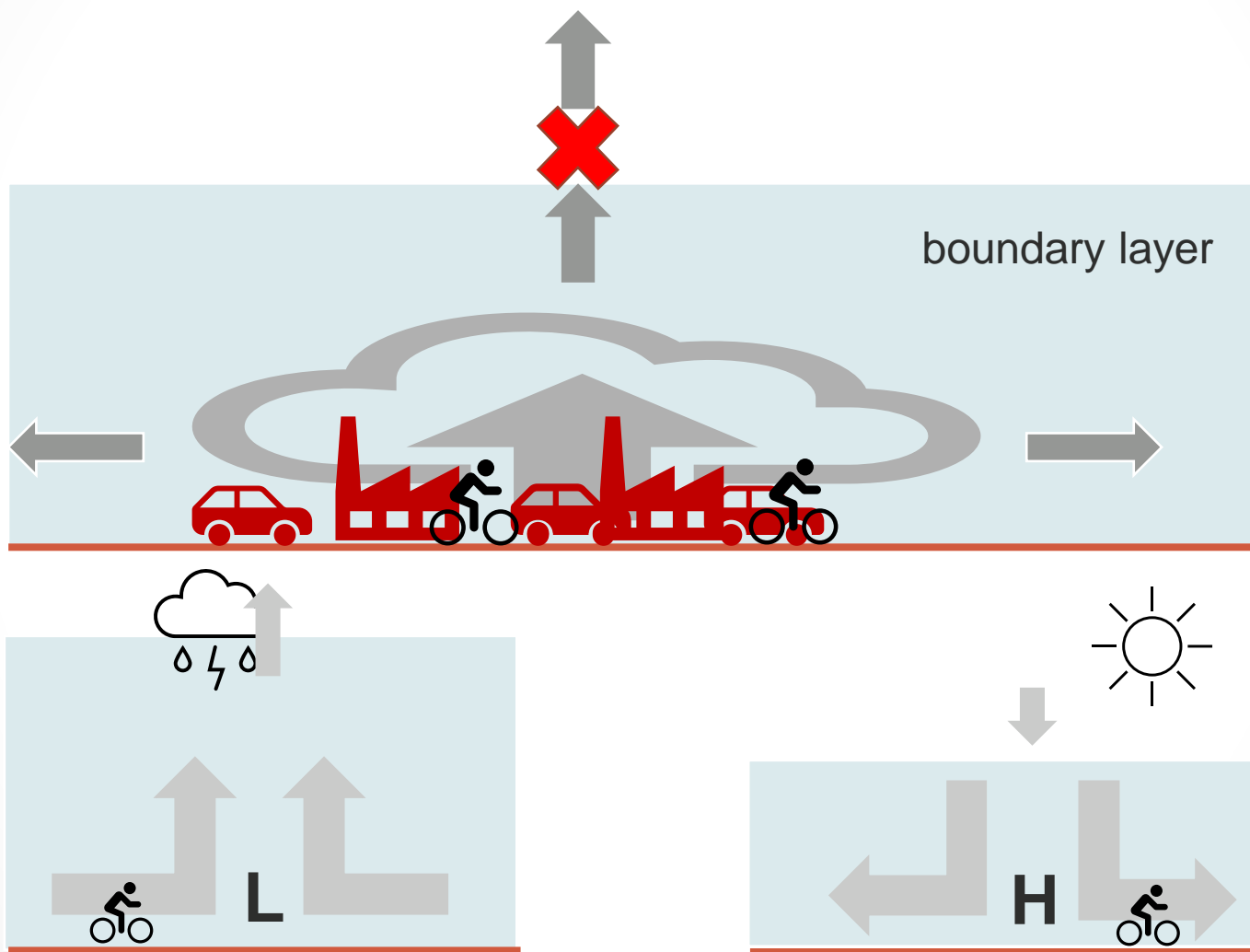
# Exercise 2020: Can we observe Corona lockdown effects in our measurements?

## Statistical Approach

- Assumption:  
NO<sub>2</sub> produced in large time period is independent of time of day & of weather
- Weather effect is instantaneous:  
 $NO_{2,observed} = NO_{2,emitted} * f(Var\ 1, Var\ 2, ..)$
- Averaging over time gives  $f(Var\ 1, Var\ 2, ..)$
- Inversion (with stabilisation bij averaging) gives  $NO_{2,emitted}$
- **Conclusions:**  
**yes** we can observe the Corona lockdown  
wind speed is important factor in all models (NO2cor1, NO2cor2, NO2cor3, NO2cor4)



# Complex pollution transport in atmospheric boundary layer



# Exercise 2023:

## Can we quantify firework source strength?

## Can we compare years with our measurements?

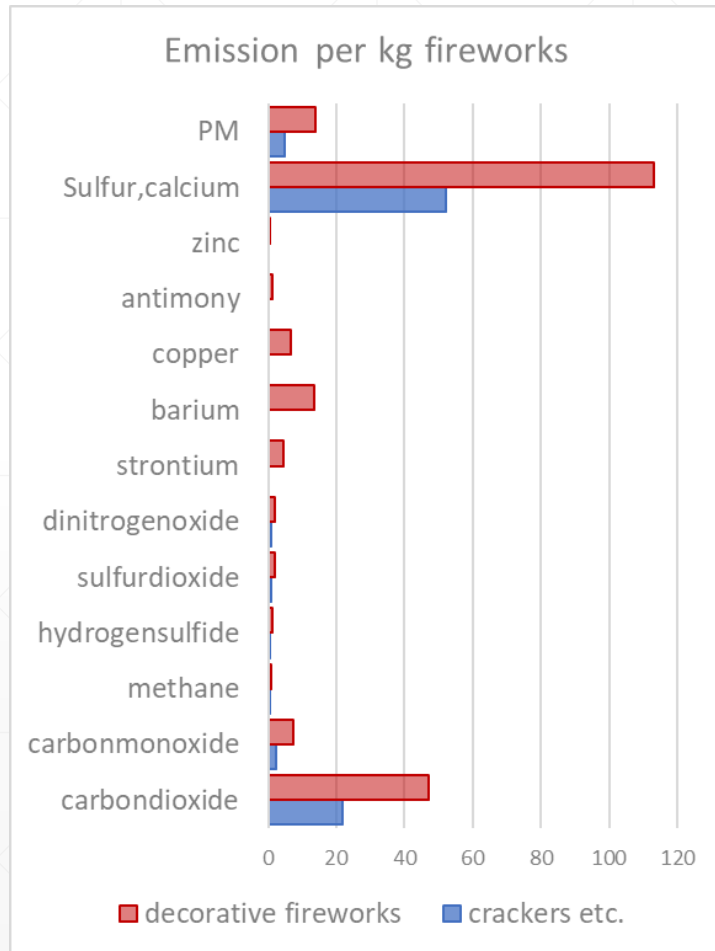
- Larger volume of fireworks sold in 2022 than in previous years
  - Only decorative fireworks allowed – no firecrackers (some 15% of expenditure in 2019-2020)
- According to Belangenvereniging Pyrotechniek Nederland (BPN):
  - Inflation effect: 10 %
  - Rest: volume

*Differences in volume and chemical composition*

	Spent (legal)	Illegal import	Legalities
2019-2020	77 M€	Yes Quantity?	
2020-2021		Yes Quantity?	Ban (Corona)
2021-2022		Yes Quantity?	Ban (Corona)
2022-2023	110 M€	Yes Quantity?	Only decorative fireworks allowed



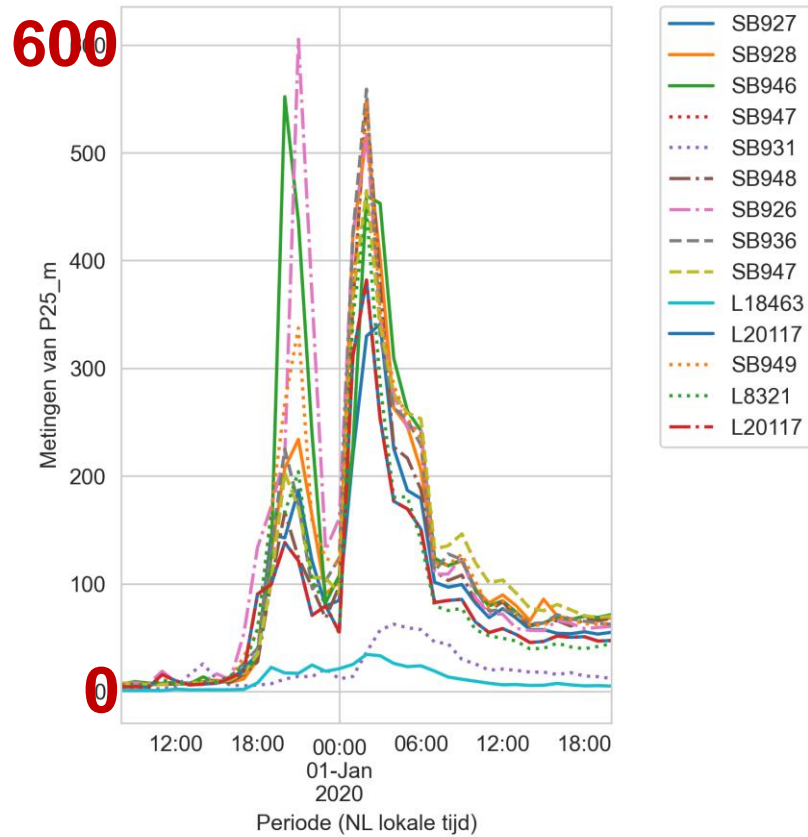
# Exercise 2023: Decorative fireworks produce more pollution than cracker type fireworks



	Spent (legal)	Illegal import	Legalities
2019-2020	77 M€	Yes Quantity?	
2020-2021		Yes Quantity?	Ban (Corona)
2021-2022		Yes Quantity?	Ban (Corona)
2022-2023	110 M€	Yes Quantity?	Only decorative fireworks allowed

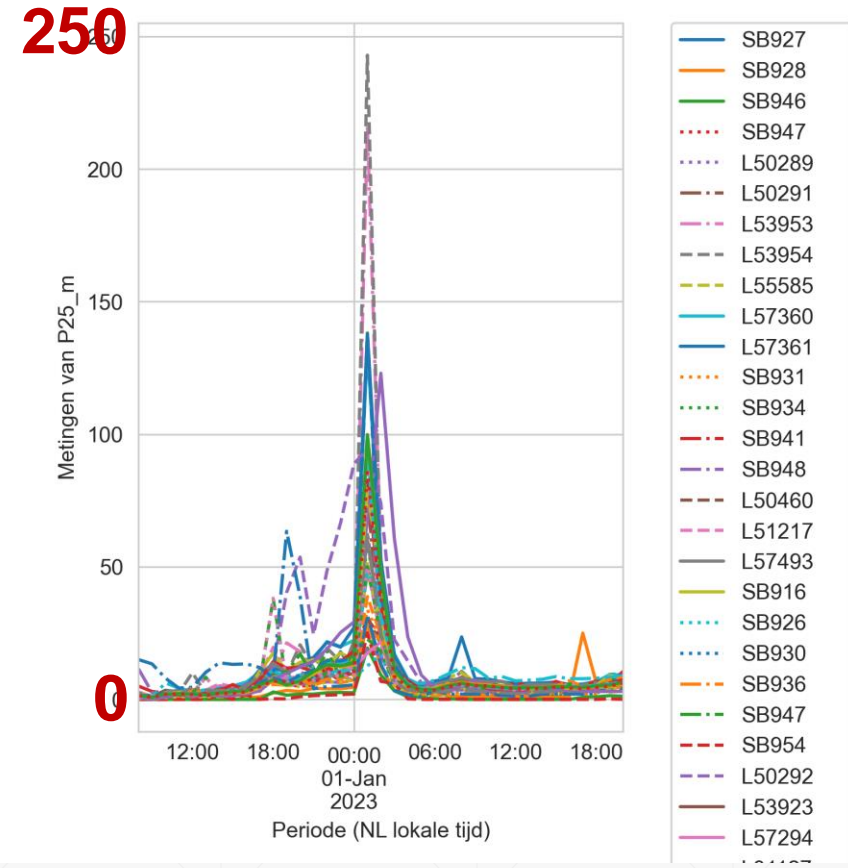
# How to compare? 2019-2020

PM<sub>2.5</sub> (gemeten) Meetwaarden (per 1 uren) - gemeten bij de stations



# Raw data, PM<sub>2.5</sub> 2022-2023

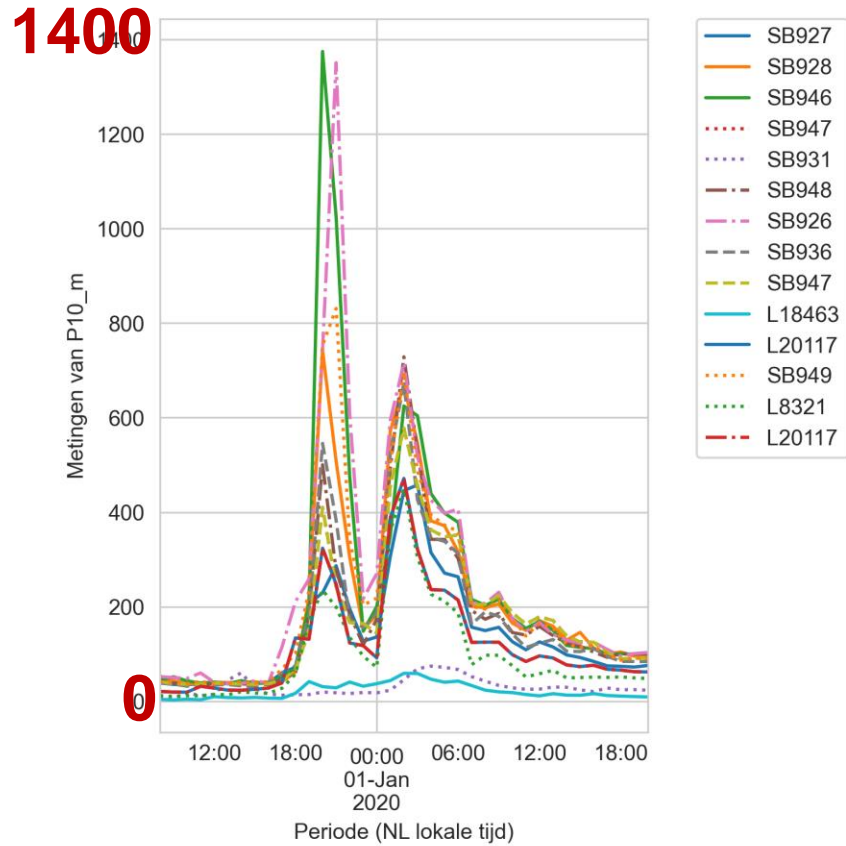
PM<sub>2.5</sub> (gemeten) Meetwaarden (per 1 uren) - gemeten bij de stations



Many more stations

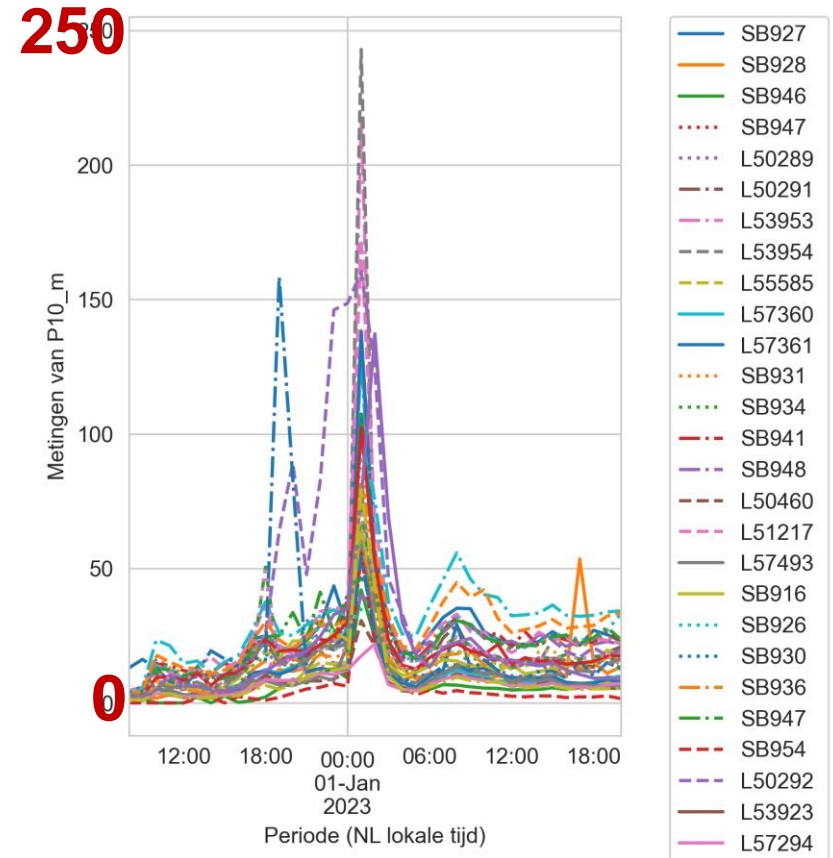
# How to compare? 2019-2020

PM<sub>10</sub> (gemeten) Meetwaarden (per 1 uren) - gemeten bij de stations



# Raw data, PM<sub>10</sub> 2022-2023

PM<sub>10</sub> (gemeten) Meetwaarden (per 1 uren) - gemeten bij de stations



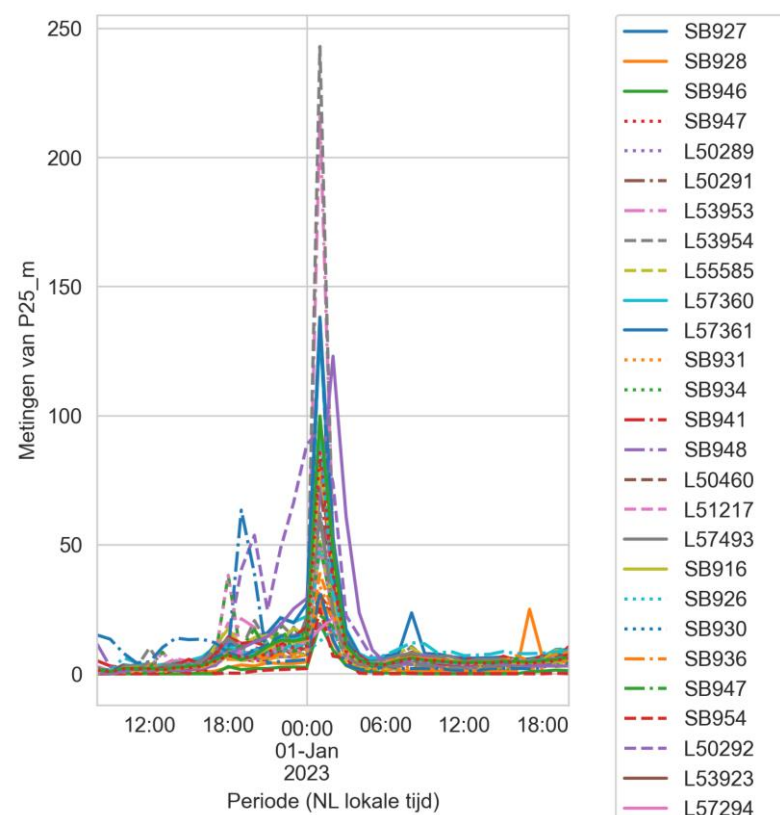
Many more stations

# Comparing different vintages

## Use of quantiles

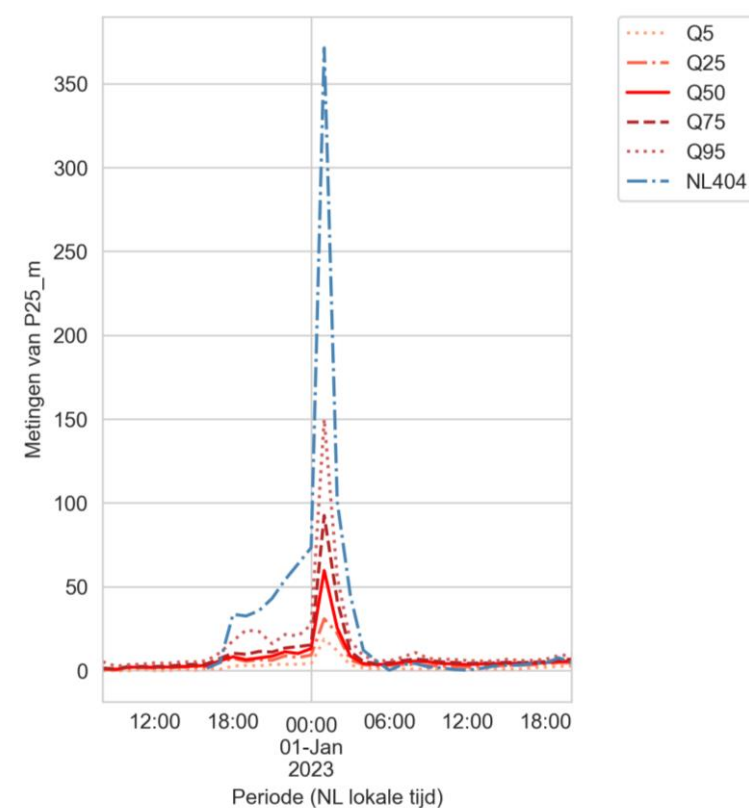
- Summarise range of data in Quantiles:
- Q5: 5 % of data has a lower value, 95 % a higher
- Q25, Q50, Q75, Q95
- Note: NL10444 data added in plot at the right

PM<sub>2.5</sub> (gemeten) Meetwaarden (per 1 uren) - gemeten bij de stations



## to avoid outliers

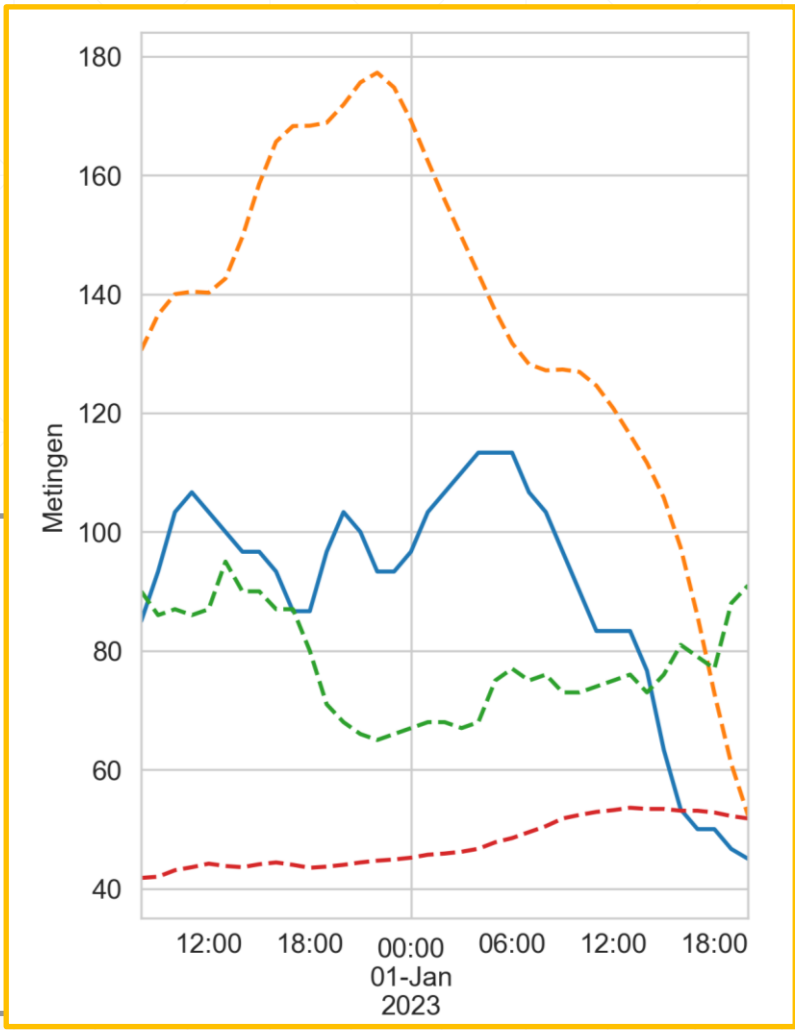
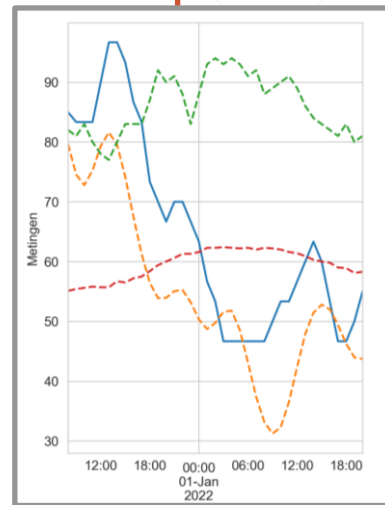
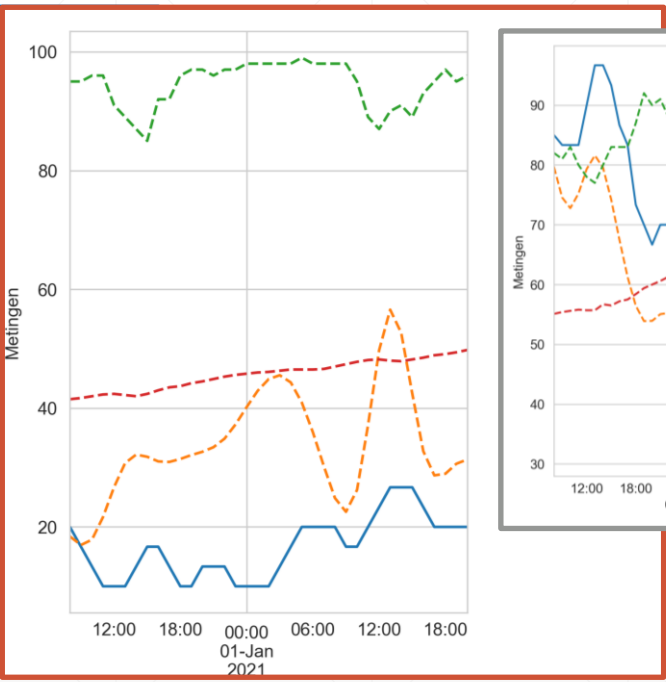
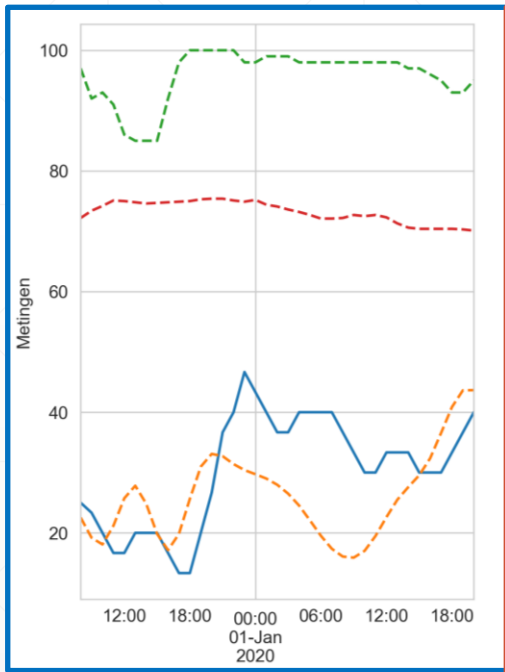
PM<sub>2.5</sub> (gemeten) Meetwaarden (per 1 uren) - gemeten bij de stations



# Relevant meteorological parameters

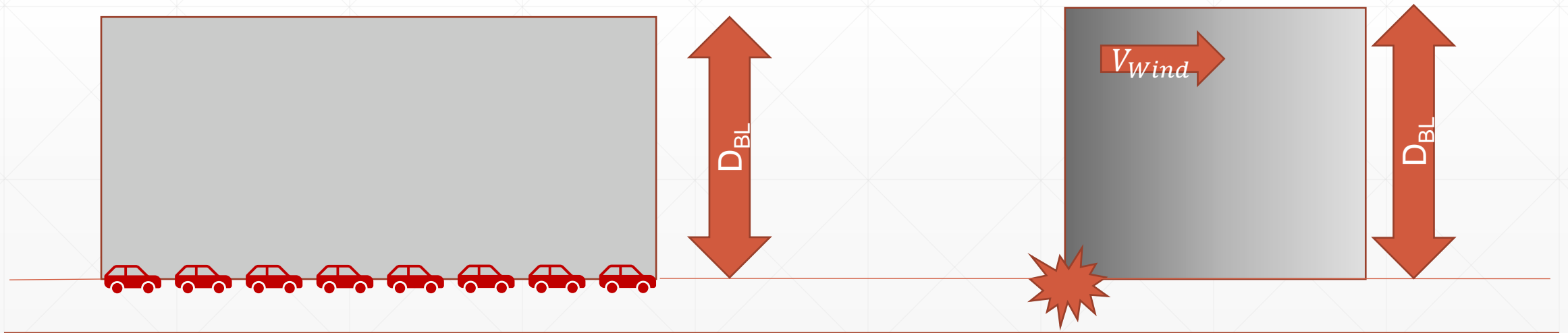
2019-2020, 2020-2021, 2021-2022, 2022-2023

- Vwindm      Wind speed in 1/10 m/s units
- - - grensl      Height boundary layer 10 m units
- - - LVocht      Relative humidity in % rh
- - - Ldruk960      Air pressure in hPa – 960 hPa  
= mbar -960 mbar



# Models for dissipation of pollution

- Homogeneous surface source
  - Dissipation to higher atmosphere
  - Equilibrium condition
  - $\rho = 1/D_{BL} \approx 1/V_{Wind}$
- Point source
  - Dissipation laterally and to higher atmosphere
  - $\rho = 1/V_{Wind} \times D_{BL}$

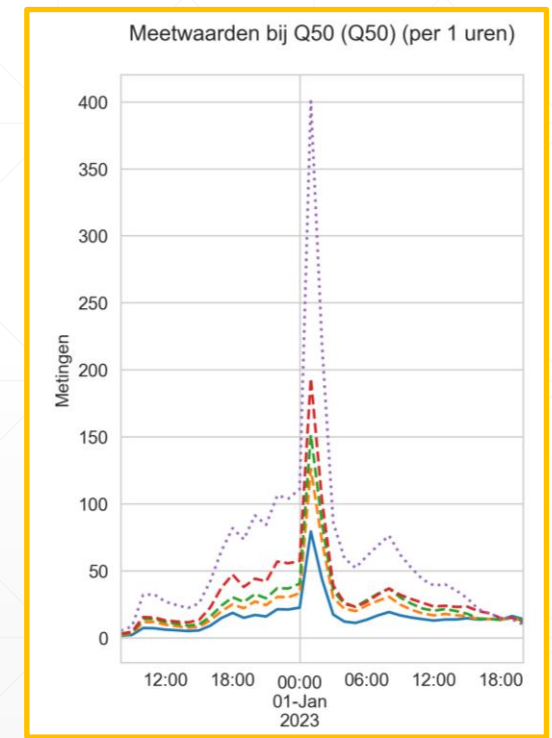
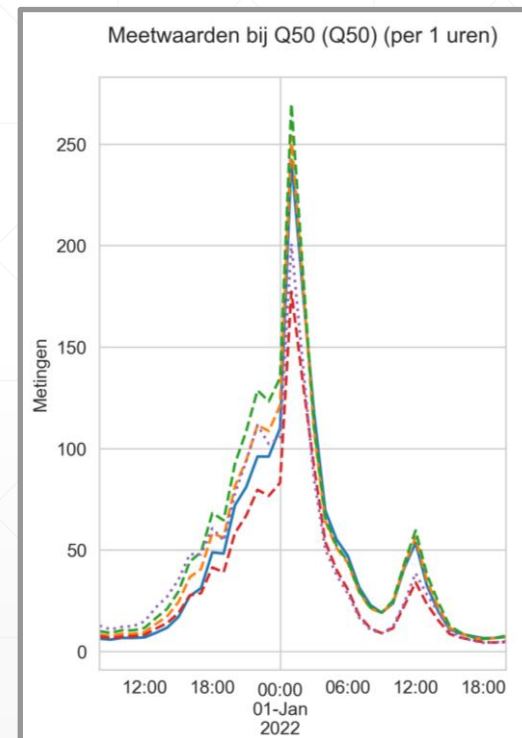
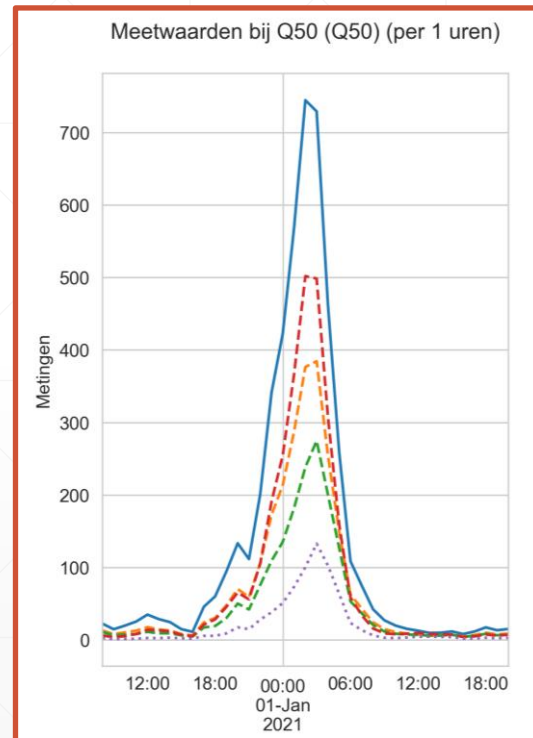
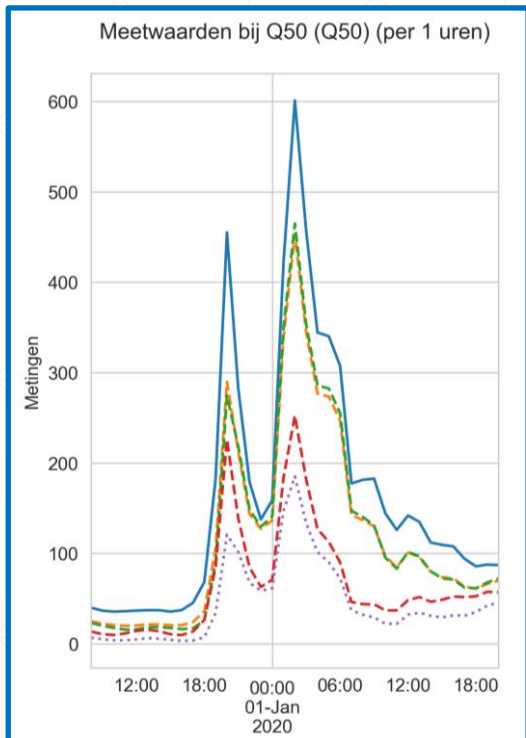


# Estimated emissions PM<sub>10</sub>

2019-2020, 2020-2021, 2021-2022, 2022-2023

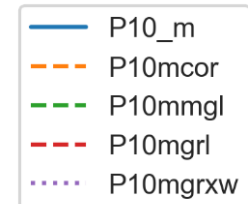
- P10\_m
- - - P10mcor
- - - P10mmgl
- - - P10mgrl
- ⋯ P10mgrxw

Original measurement  
 Correction NO2  
 Correction wind speed ~ grenslaag  
 Correction grenslaag  
 Correction grenslaag x wind speed

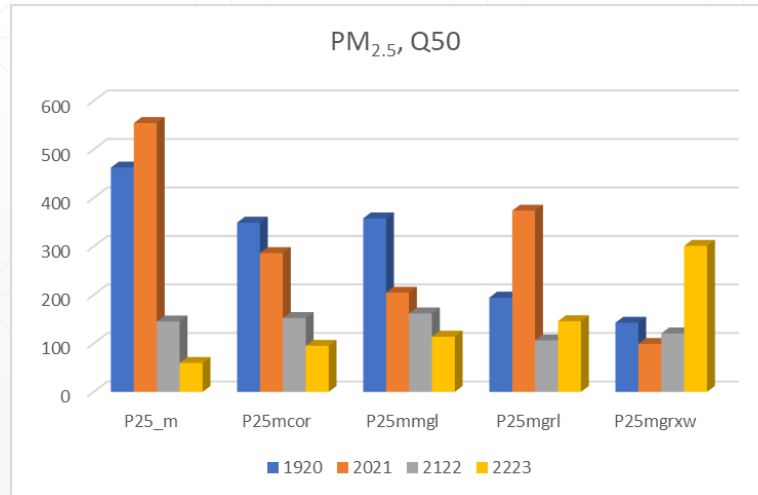
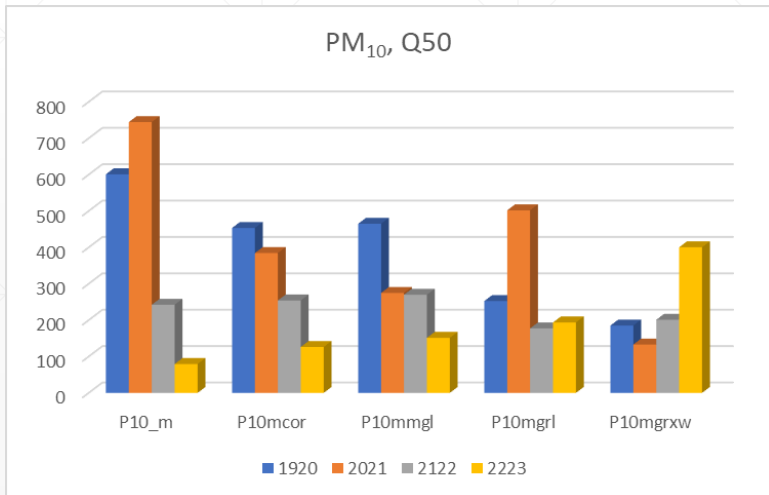
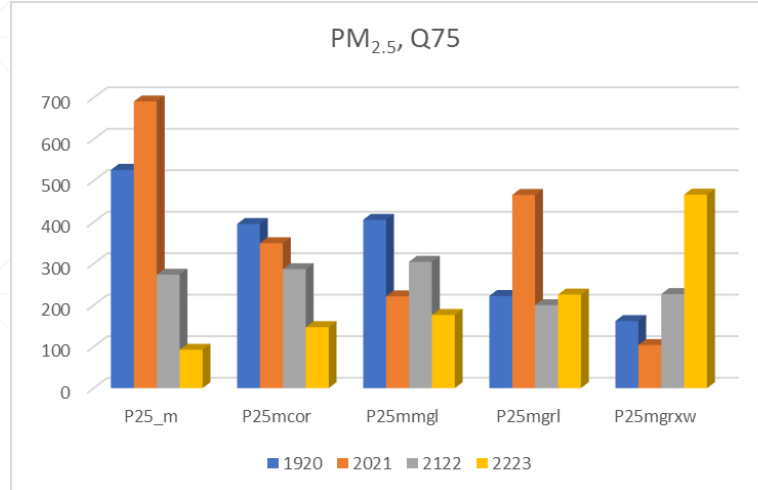
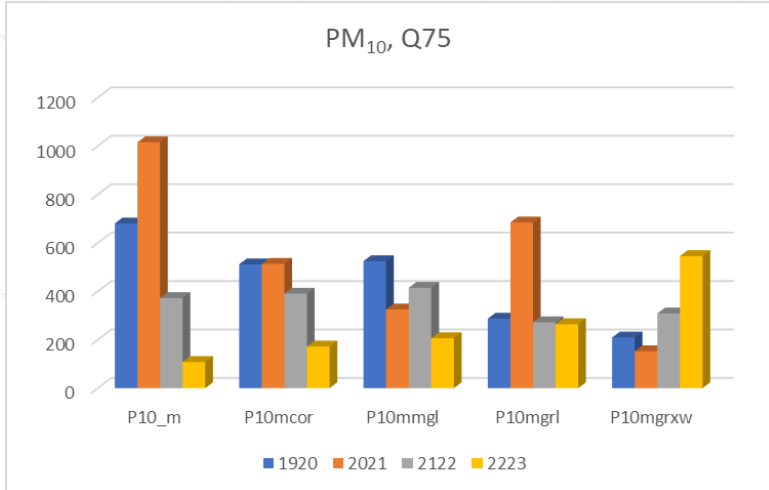


# Maximum Pollution PM<sub>10</sub>, PM<sub>2.5</sub>

2019-2020, 2020-2021, 2021-2022, 2022-2023



Original measurement  
 Correction NO2  
 Correction wind speed~ grenslaag  
 Correction grenslaag  
 Correction grenslaag x wind speed



Conclusion:

Only correction for boundary layer & wind speed both give expected behaviour

Point source behaviour

But:

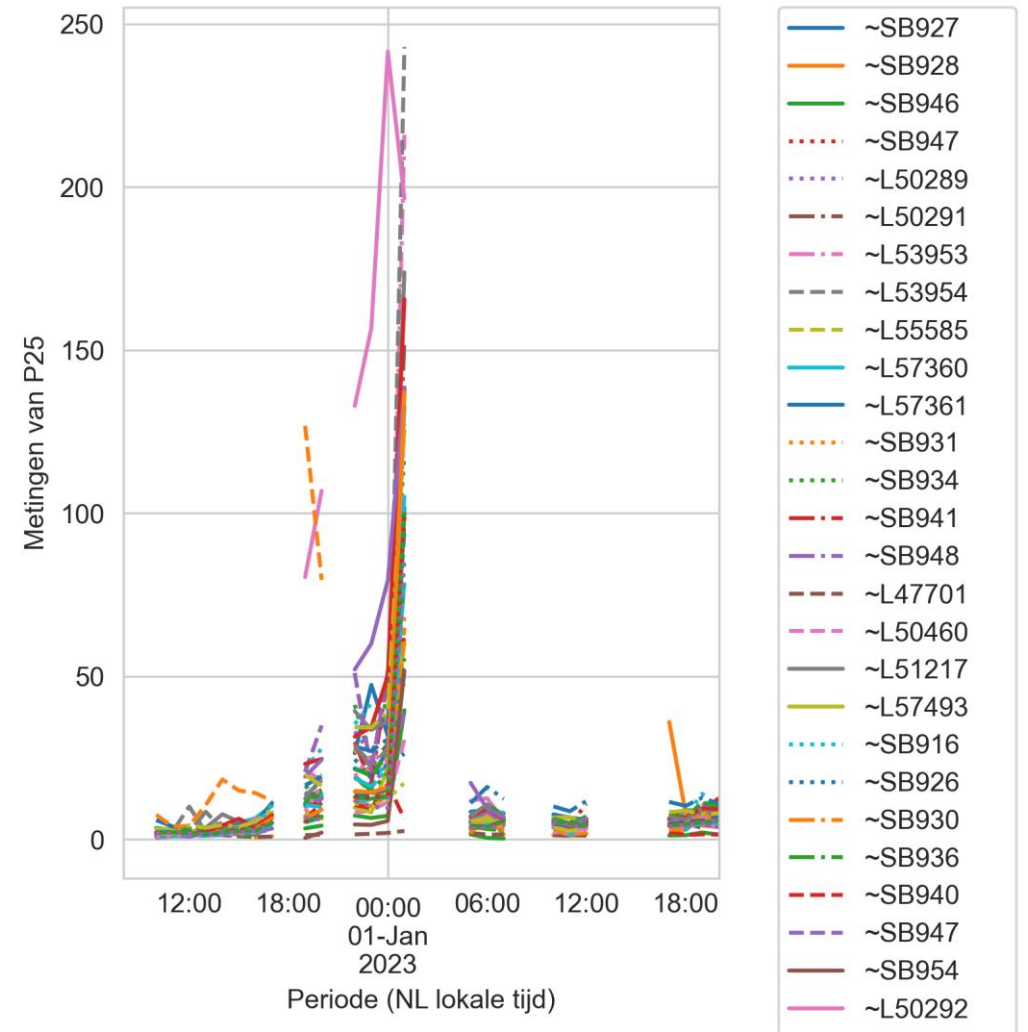
Data without RIVM calibration /leveling



# From sensors to numbers

- Sensor → sensorcommunity
- Sensorcommunity → RIVM
- RIVM processing:
  - Calibration / leveling to RIVM stations
  - Resampling to 1 hour interval
- Sources of data used by LV2
  - Samenmeten.rivm.nl vs 1.5 (uncalibr)
  - RIVM API (uncalibr & calibr)
- Issues:
  - How to compare different vintages?
  - Understanding calibration / leveling
  - Missing data

PM<sub>2.5</sub> (geijkt) Meetwaarden (per 1 uren) - gemeten bij de stations



Data from RIVM API (calibrated)

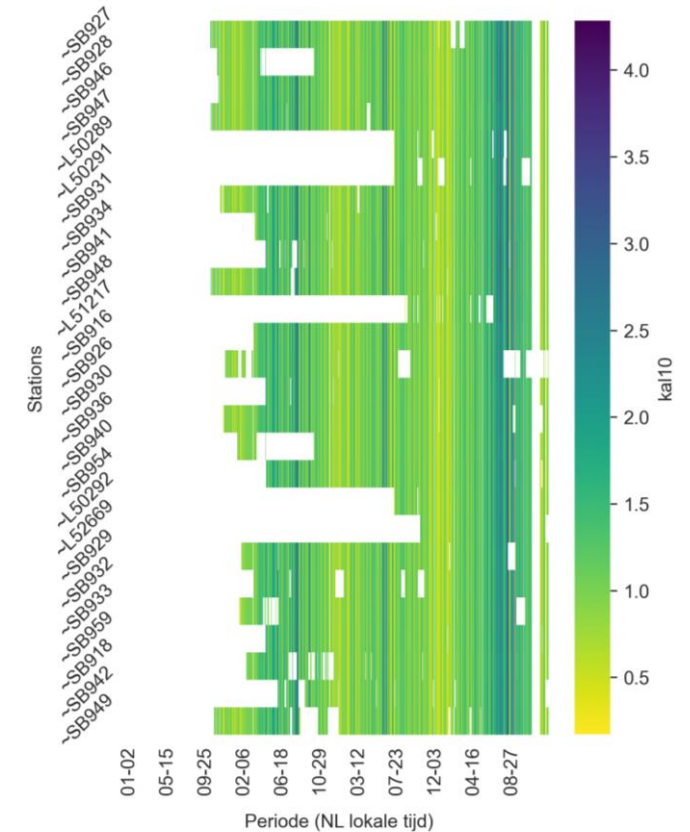
# RIVM calibration procedure

- Compare data from sensors in neighbourhood of official RIVM station with data of this station to derive local calibration factor.
  - Are these sensors representative?
  - Is pollution at station comparable to the pollution at the sensors? Location effects? Noise sensitivity?
- Calculate calibration factor for all sensors by inverse distance weighting from all RIVM stations
  - Inverse distance weighting is very simple approach to gridding and contouring
- Issues:
  - Calculation takes time → gaps in data
  - RIVM stations have own calibration pause (at 2 in the morning)

PM10 Calibration factors  
for LV2 stations

SDS011 stations only  
2019 2020 2021 2022

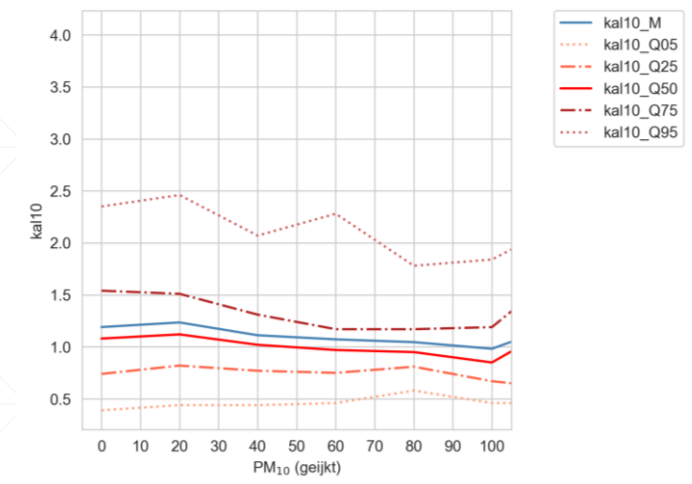
kal10 Meetwaarden- Overzicht Metingen (per 4 uren) metingen versus tijd



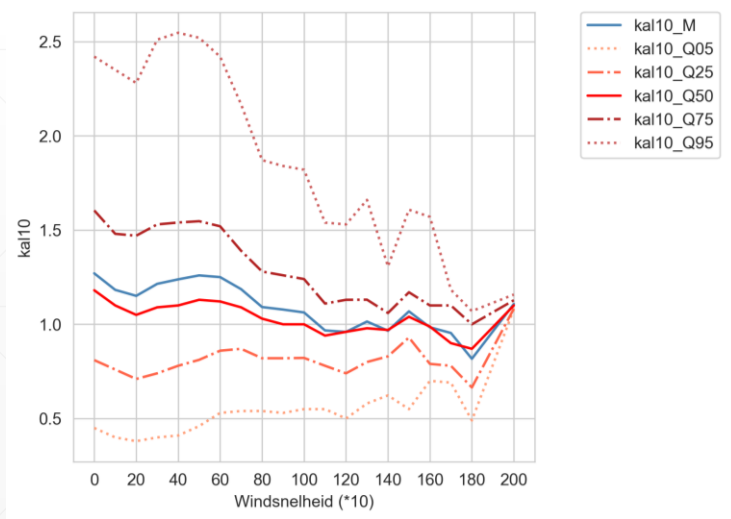
# RIVM calibration procedure PM<sub>10</sub>

- Calibration effects quite significant
  - Influenced by temperature, humidity
  - Both amplifies and reduces the amplitudes
    - Mean amplification: 1.2; median 1.1

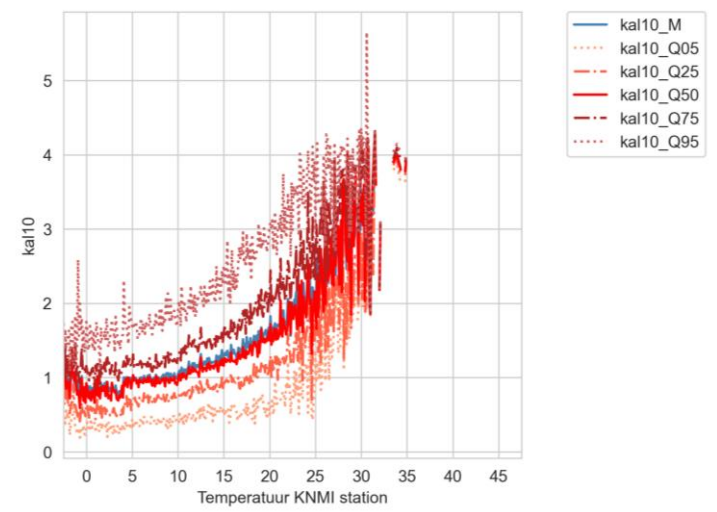
kal10 Meetwaarden-functie van P10



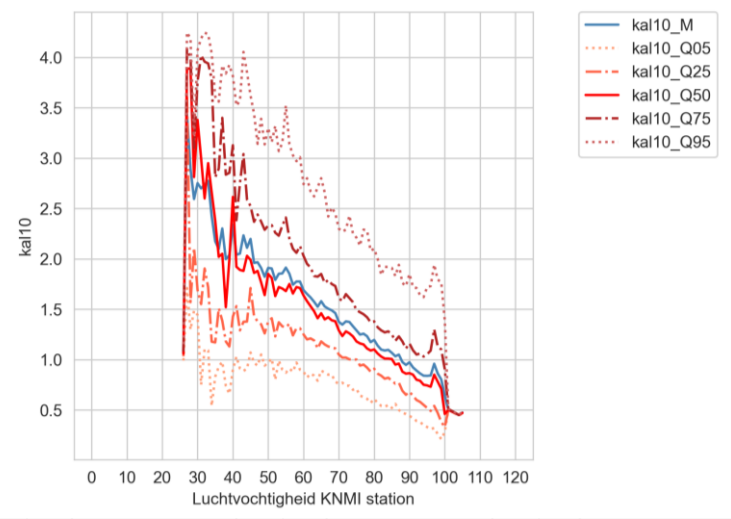
kal10 Meetwaarden-functie van Vwind



kal10 Meetwaarden-functie van TempKNMI



kal10 Meetwaarden-functie van LVocht

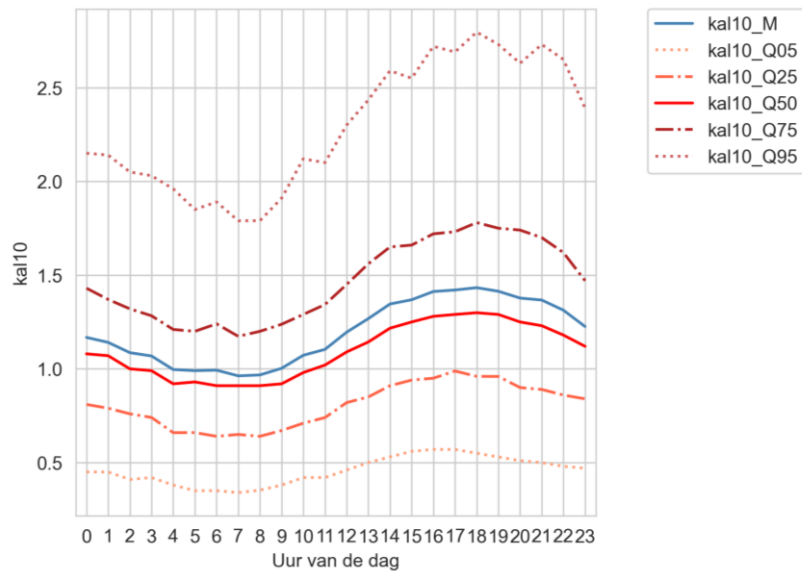


# RIVM calibration procedure

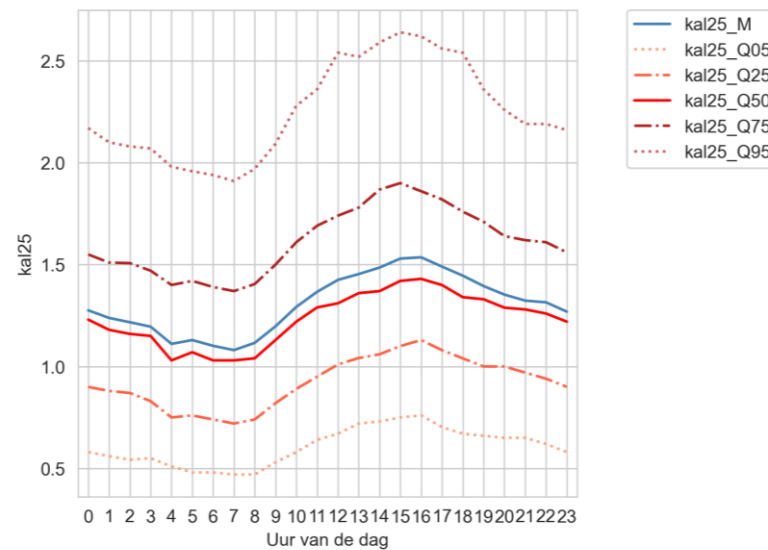
## PM<sub>10</sub> PM<sub>2.5</sub> calibration factors

- Dependencies
  - time of the day
  - season

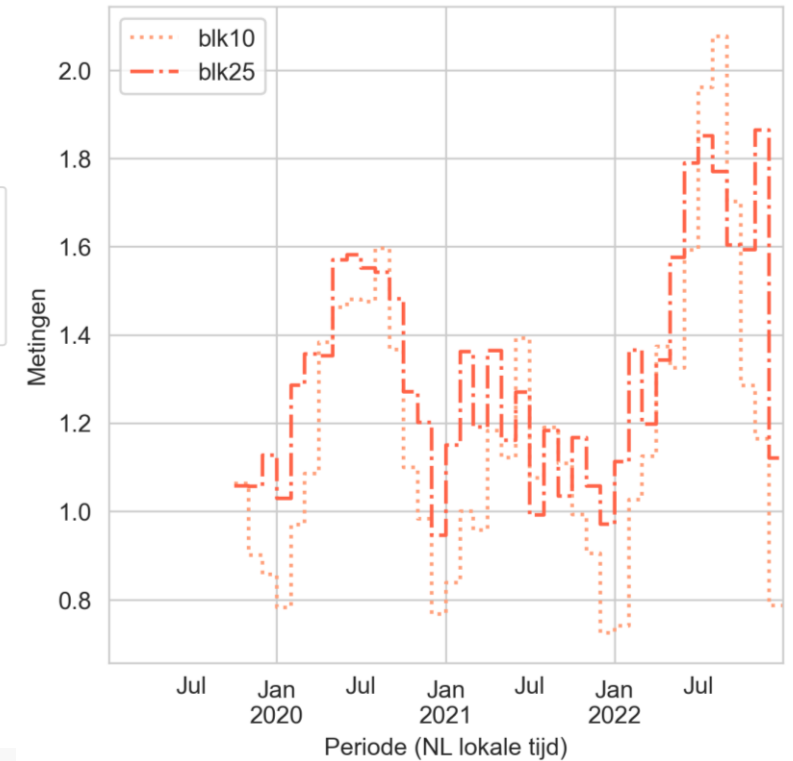
kal10 Meetwaarden-functie van Tijd



kal25 Meetwaarden-functie van Tijd



Meetwaarden bij BlokGM (BlokGM)



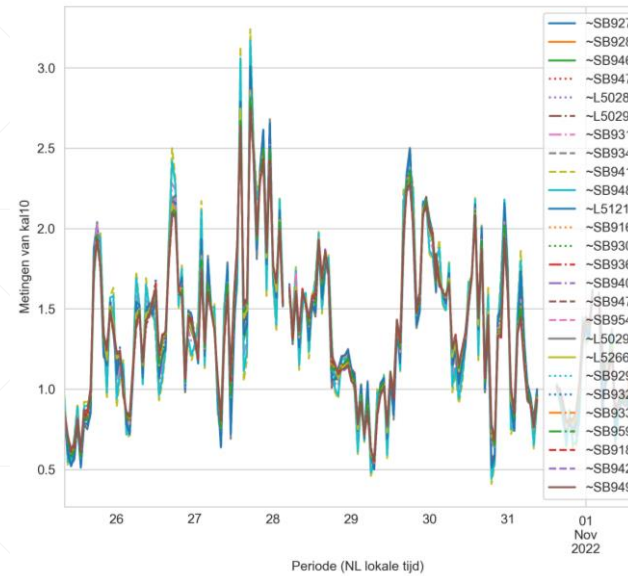
# RIVM calibration factors

## PM<sub>10</sub> PM<sub>2.5</sub>

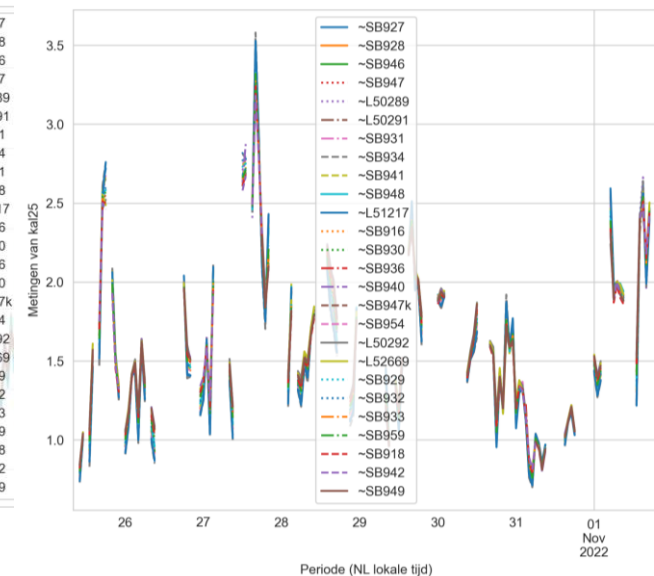
### arbitrary days

- Large variation from hour to hour
  - What is the physics?
- Gaps

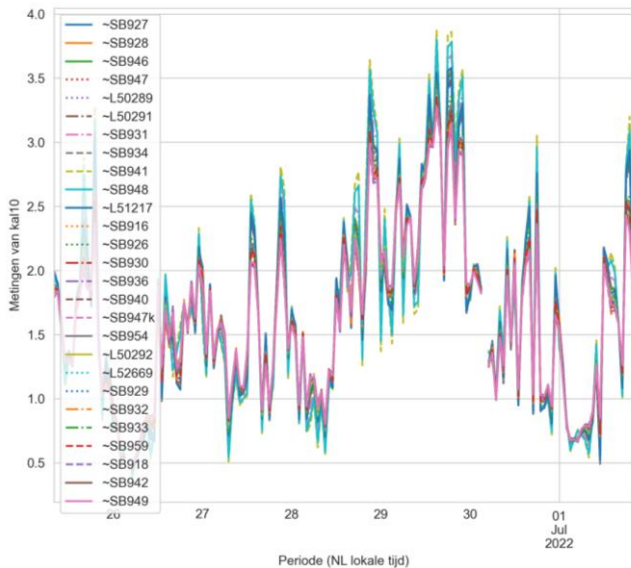
kal10 Meetwaarden - gemeten bij de stations



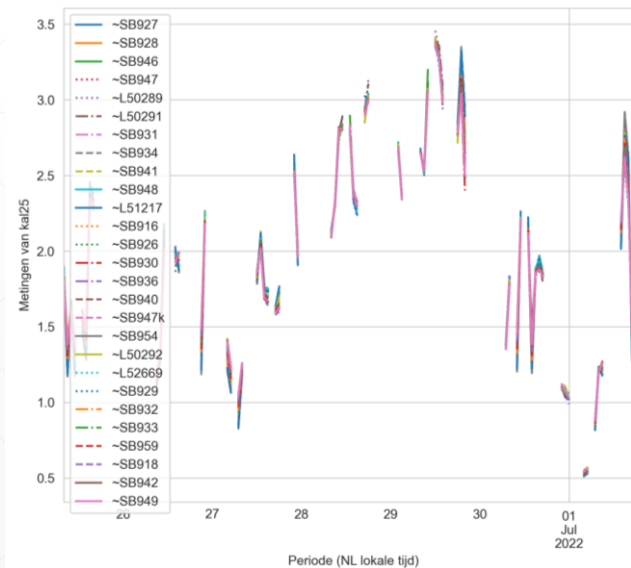
kal25 Meetwaarden - gemeten bij de stations



kal10 Meetwaarden - gemeten bij de stations



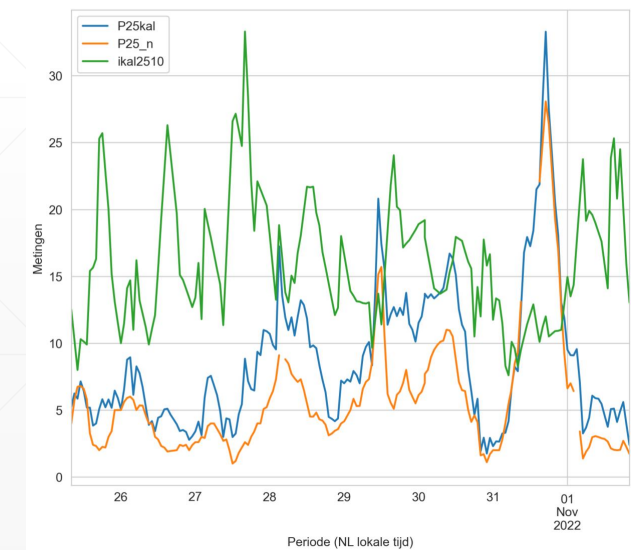
kal25 Meetwaarden - gemeten bij de stations



## Processing

- Deduce calibration factor from RIVM API data
- Interpolate
- Apply to uncalibrated data from [samenmeten.rivm.nl](https://samenmeten.rivm.nl)

Meetwaarden bij Q50 (Q50)



End June 2022

End October 2022

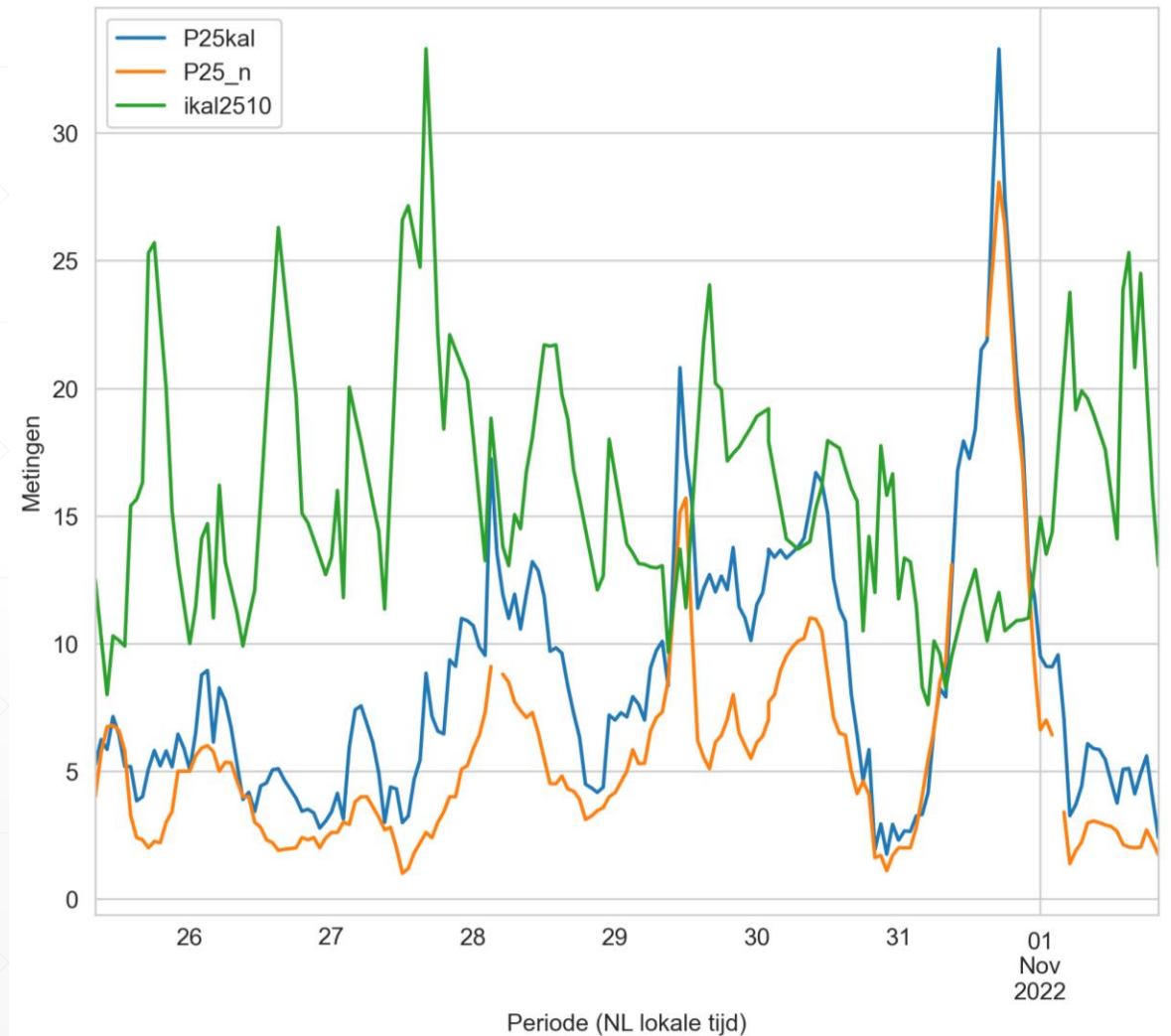
# RIVM calibration factors

## PM<sub>10</sub> PM<sub>2.5</sub>

### arbitrary days

- Processing
  - Deduce calibration factor from RIVM API data
  - Interpolate
  - Apply to uncalibrated data from [samenmeten.rivm.nl](https://samenmeten.rivm.nl)
- Observation:  
Calibrated time function shows higher frequency behaviour than original measurement

Meetwaarden bij Q50 (Q50)



End October 2022

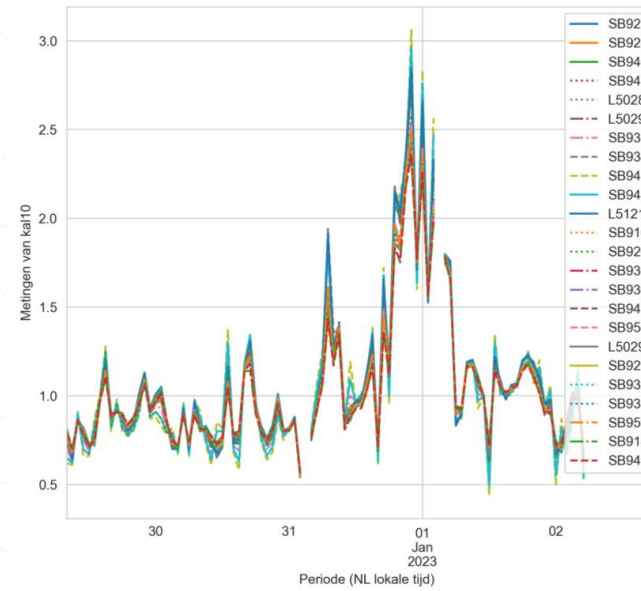
# RIVM calibration factors

## PM<sub>10</sub> PM<sub>2.5</sub>

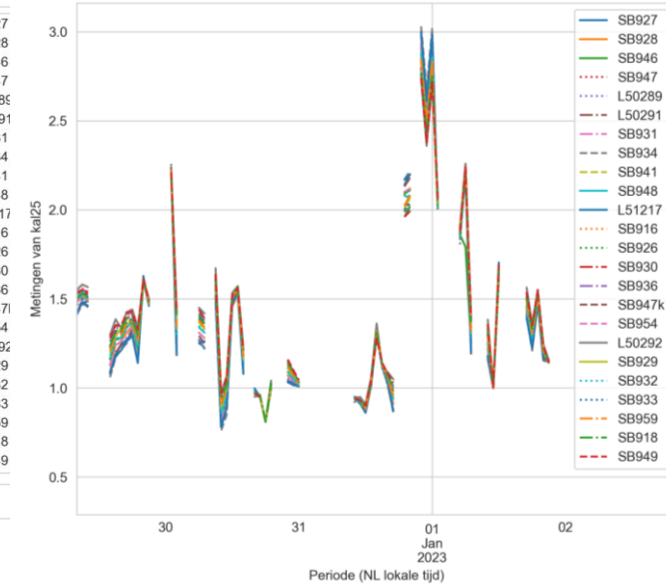
### New Years Eve

- In 2022-2023
  - Peak (amplifying with factor 2.5)
  - No such thing in previous years

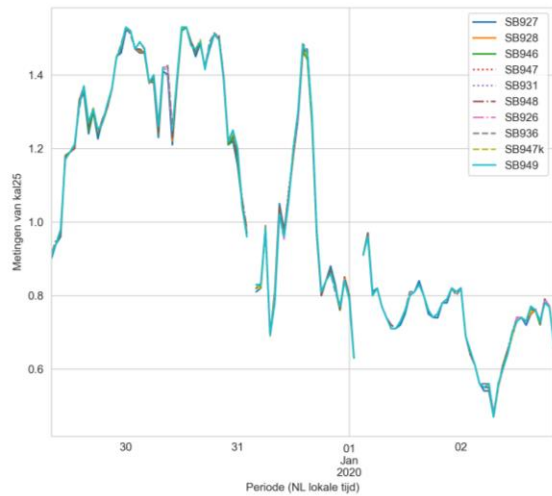
kal10 Meetwaarden - gemeten bij de stations



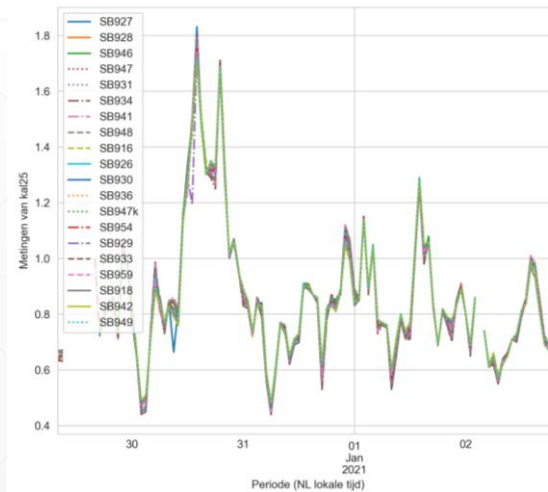
kal25 Meetwaarden - gemeten bij de stations



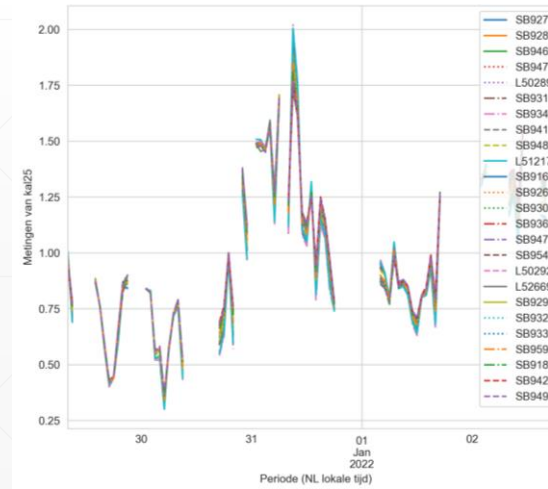
kal25 Meetwaarden - gemeten bij de stations



kal25 Meetwaarden - gemeten bij de stations



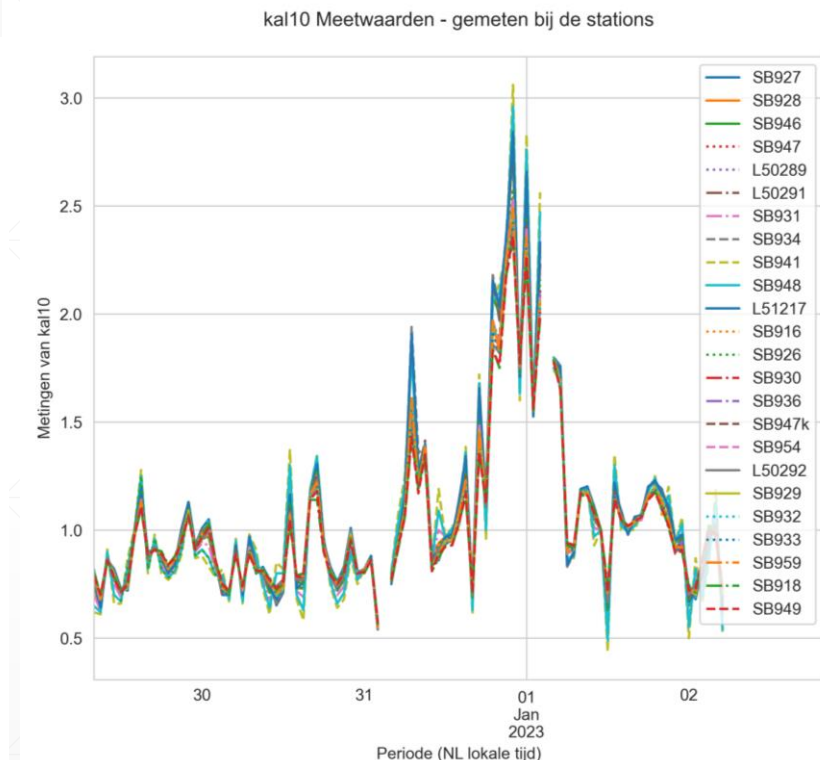
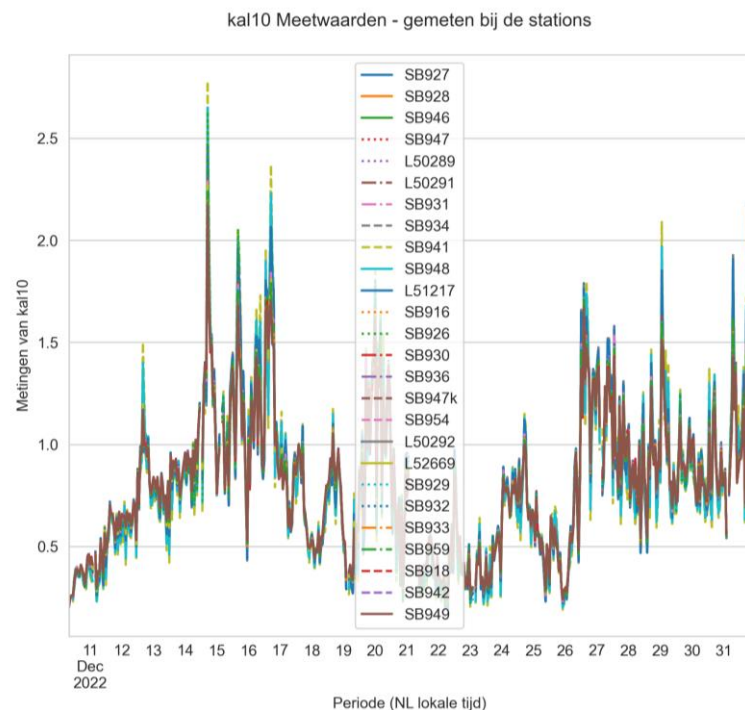
kal25 Meetwaarden - gemeten bij de stations



# RIVM calibration factors @ New Years Eve

## PM<sub>10</sub>

- Suspicion:
  - RIVM calibration station environment is not representative for the environment of the sensors used in the calibration procedure
  - In The Hague:
    - Rebecquestraat NL10404
  - Calibration CS stations:
    - Rijswijk, Leidschendam



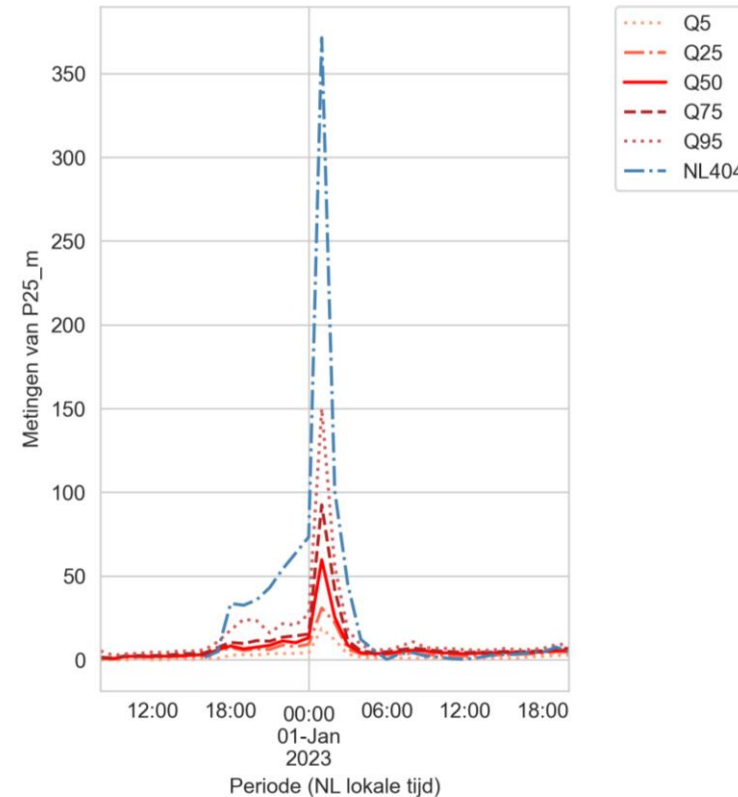


# RIVM calibration factors @ New Years Eve

## PM<sub>2.5</sub>

- Suspicion:
  - RIVM calibration station environment is not representative for the environment of the sensors used in the calibration procedure
  - In The Hague:
    - Rebecquestraat NL10404 (very high signal, starting early)
  - Calibration CS stations:
    - Rijswijk, Leidschendam

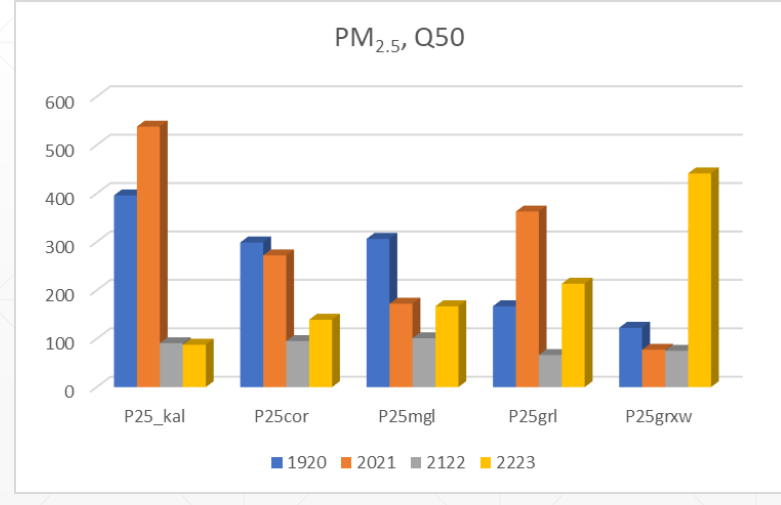
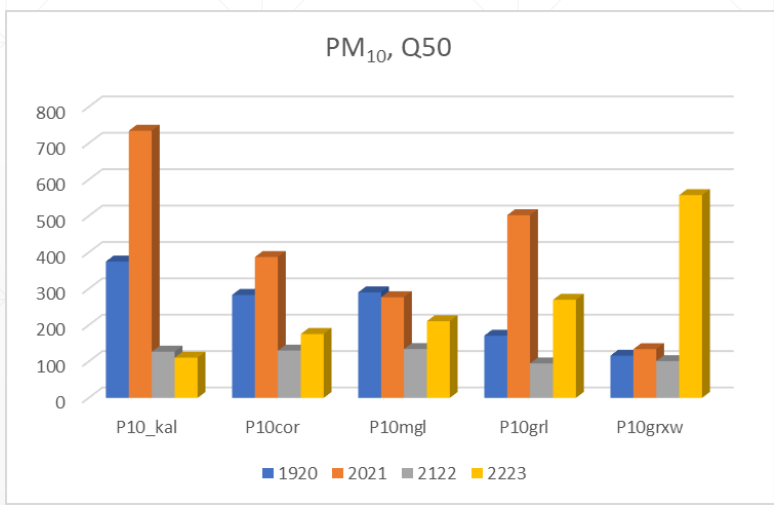
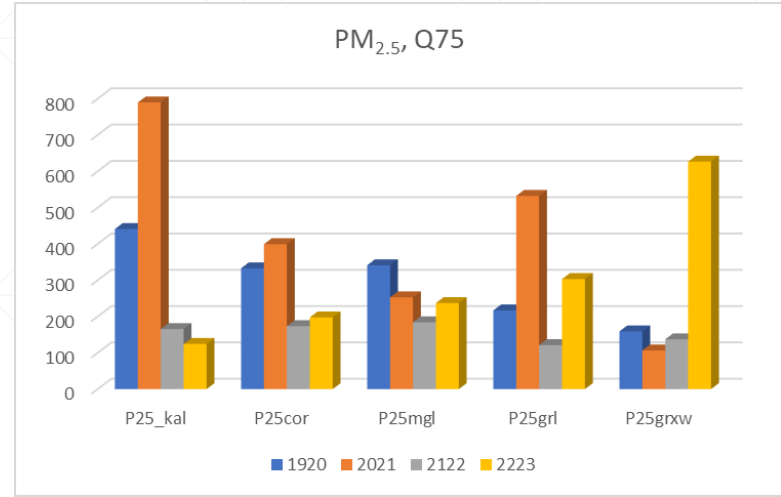
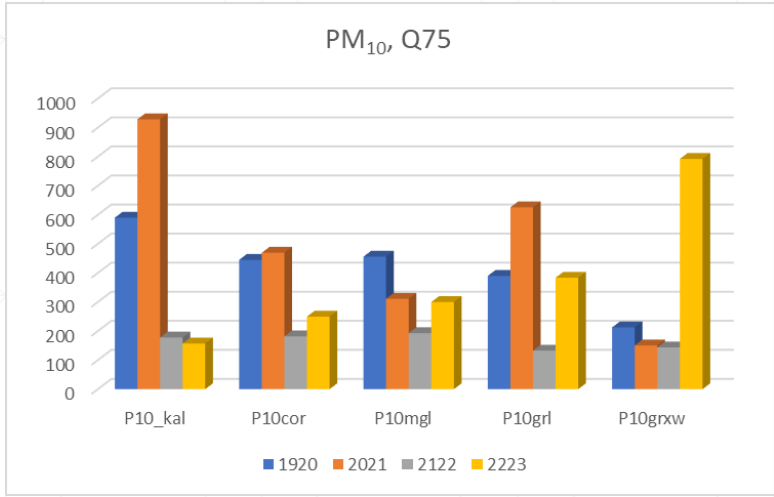
PM<sub>2.5</sub> (gemeten) Meetwaarden (per 1 uren) - gemeten bij de stations



# Maximum Calibrated PM<sub>10</sub>, PM<sub>2.5</sub>

2019-2020, 2020-2021, 2021-2022, 2022-2023

- P10kal Calibrated measurement
- - - P10cor Correction NO2
- - - P10mgl Correction wind speed~ grenslaag
- - - P10grl Correction grenslaag
- P10grxw Correction grenslaag x wind speed

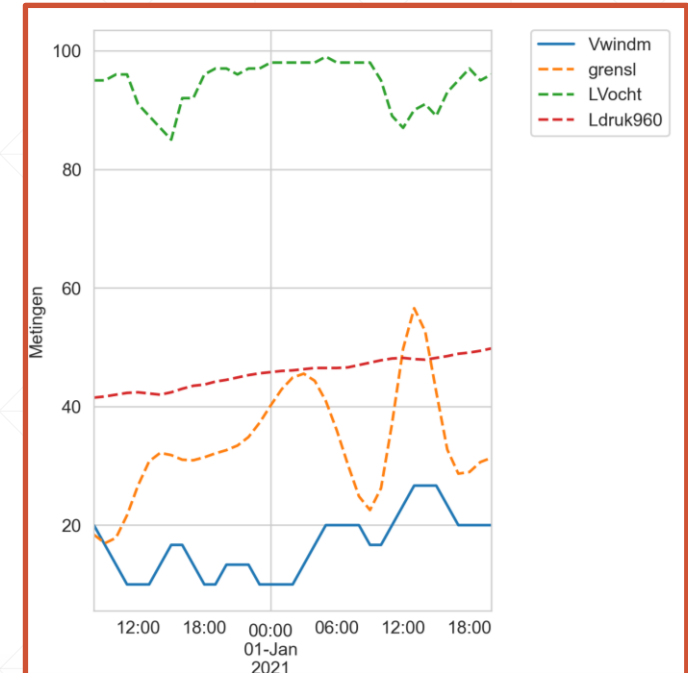


Conclusion:  
2020-2021 response always higher than expected (Wind speed issue?)

Correction using boundary layer essential to ensure that 2022-2023 pollution exceeds 2019-2020

# Conclusions

- Meten = Weten?
  - Data are not what they seem to be.
- Correction for meteorological effects at fireworks not straightforward
  - Simple model fails for situation of very low wind speed
  - Boundary layer thickness is rather critical parameter
- RIVM calibration method
  - changes the signal to a significant extent, and
  - introduces high frequent behaviour
  - Large variability in sensor signatures dependent on distance to firing of the fireworks
    - In how far does that affect the calibration procedure?



Acknowledgments: Walter Takens (Gouda), Rob Groenland (KNMI), Nino van der Wilk, Diederik van Hemert, Wynfrith Meijwes (LV2)