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National Institute for Public Health and the Environment
Ministry of Health, Welfare and Sport

Benchmark of Data Fusion using sensor data

FAIRMODE WG6, Dublin, October 7, 2024

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Agenda WG6 Monday

- Quick process recap
- General benchmark setup
- Presentation of results participants including questions
  - INERIS Alicia Gressent, remote
  - MetNo Lewis Blake, remote
  - ISSeP Fabian , recorded/remote
  - CERC Jenny Stocker
  - RIVM Joost Wesseling
- First comparison between preliminary results, Joost Wesseling
- Discussion

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Setup

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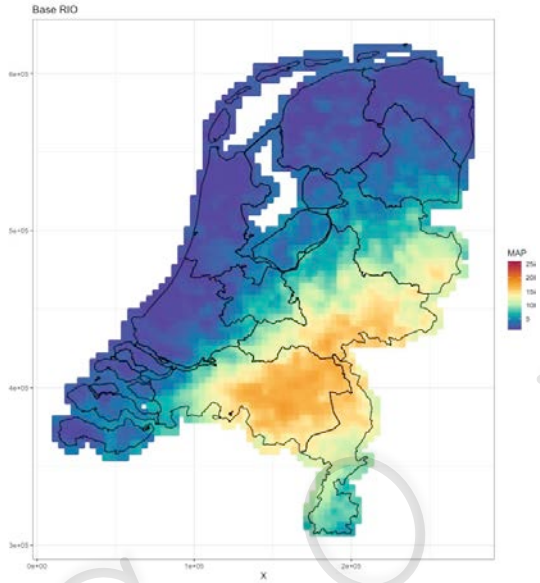
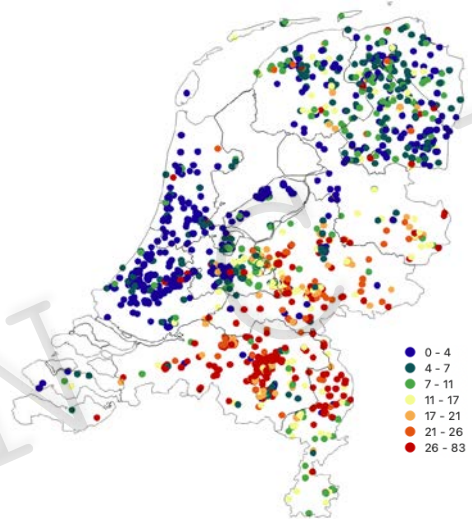
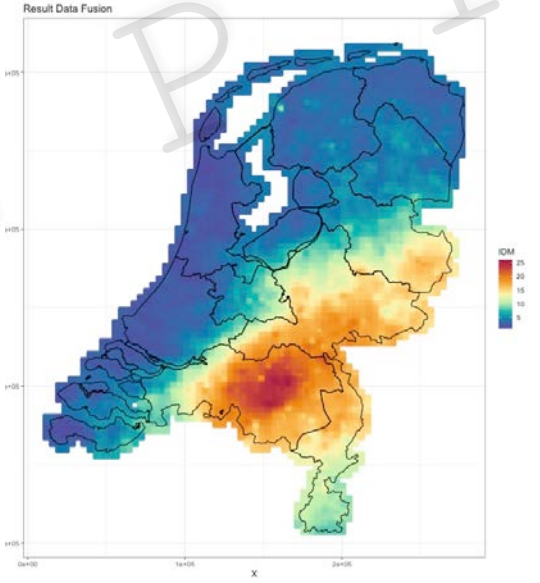
Sjoerd van Ratingen, Joost Wesseling, RIVM

Data fusion with sensors

Starting from a concentration field based on official measurements and many sensors, what is the best combination?







CONCEPT

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Since Paris...

- Benchmark for data fusion of **~ 1800 sensors** in the **Netherlands** together with **RIO model results**
- Continued search for organizations, interested the sensor data fusion benchmark.
- Four live meetings to converge on benchmark setup
- Outcome is six organizations now actively testing fusion models within the benchmark
  VITO, INERIS, MetNO, ISSeP, CERC, RIVM
  Other interested parties up to date via meetings and correspondence.
- Discussions
  - Input /output formats, Most interesting data sets to use which period
  - Variants / validation, Uncertainties
  - Use of reference stations
- Testing with preliminary data from participants

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Options DF runs

Run	Official measurements	Sensor measurements	RIO map	Goal
Basic run	**All**	Raw and calibrated using **all** measurements	Based on **all** official measurements	Compare results from different data fusion methods
Option 1a	Leave out 1-2 official measurements in each province	Raw and calibrated using **all** measurements	Leave out the same 1-2 measurements in each province	Can **good** sensors compensate for less official measurements?
Option 1b	Leave out 1-2official measurements in each province	Leave out the same 1-2 measurements in each province in the calibration	Leave out the same 1-2 measurements in each province	Can **not so good** sensors compensate for less official measurements?
Option 2a	Leave out **all** official measurements in **one** province	Raw and calibrated using **all** measurements in **all** provinces	Based on **all** official measurements in the **other** provinces	Can **good** sensors compensate for a gap in the official measurements?
Option 2b	Leave out **all** official measurements in **one** province	Raw and calibrated using **all** measurements in the **other** provinces	Based on **all** official measurements in the **other** provinces	Can **not so good** sensors compensate for a gap in the official measurements?

Analysis of 1st results Jan/Aug 2024

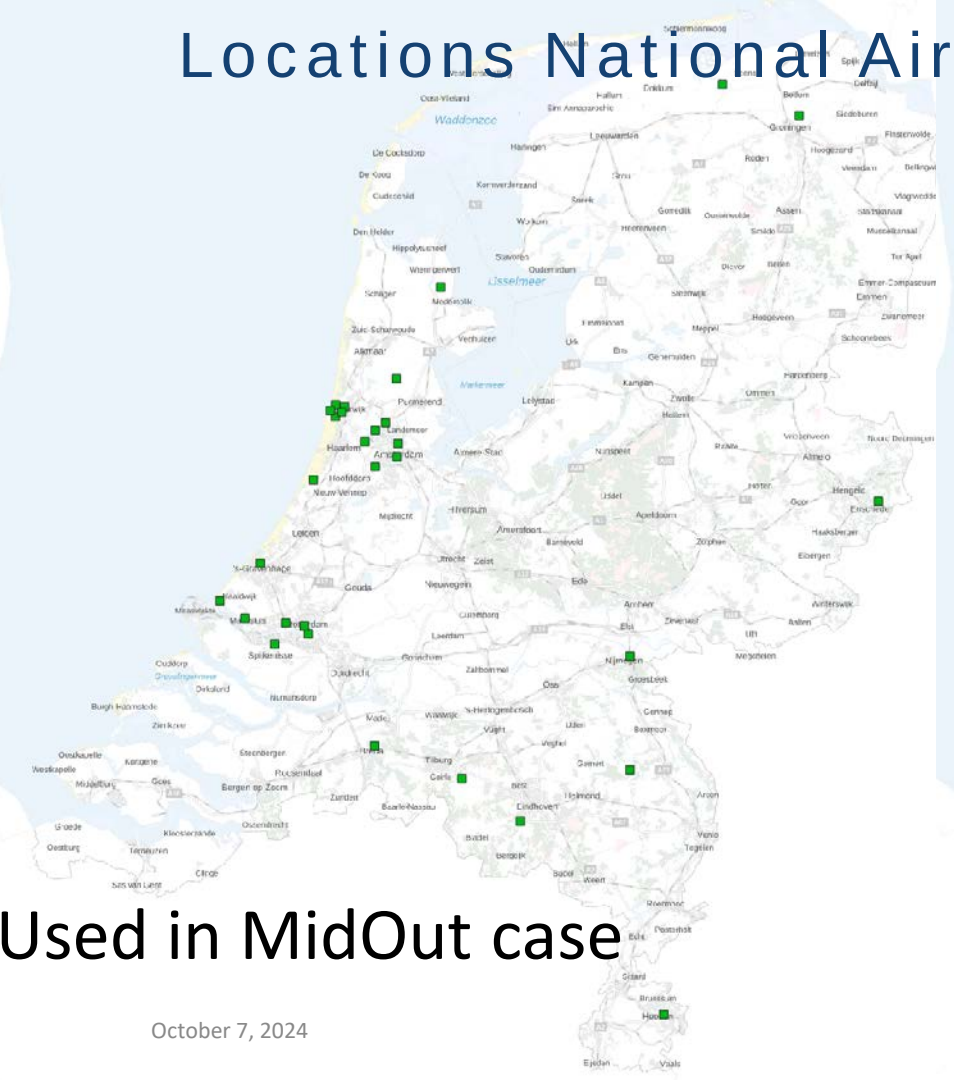
- Available independent official data to test the results of RIO and the data fusion.
- Interesting periods to test the data fusion.
- Analyses …
- Results.
- Conclusions.

Locations National Air Quality network (LML)

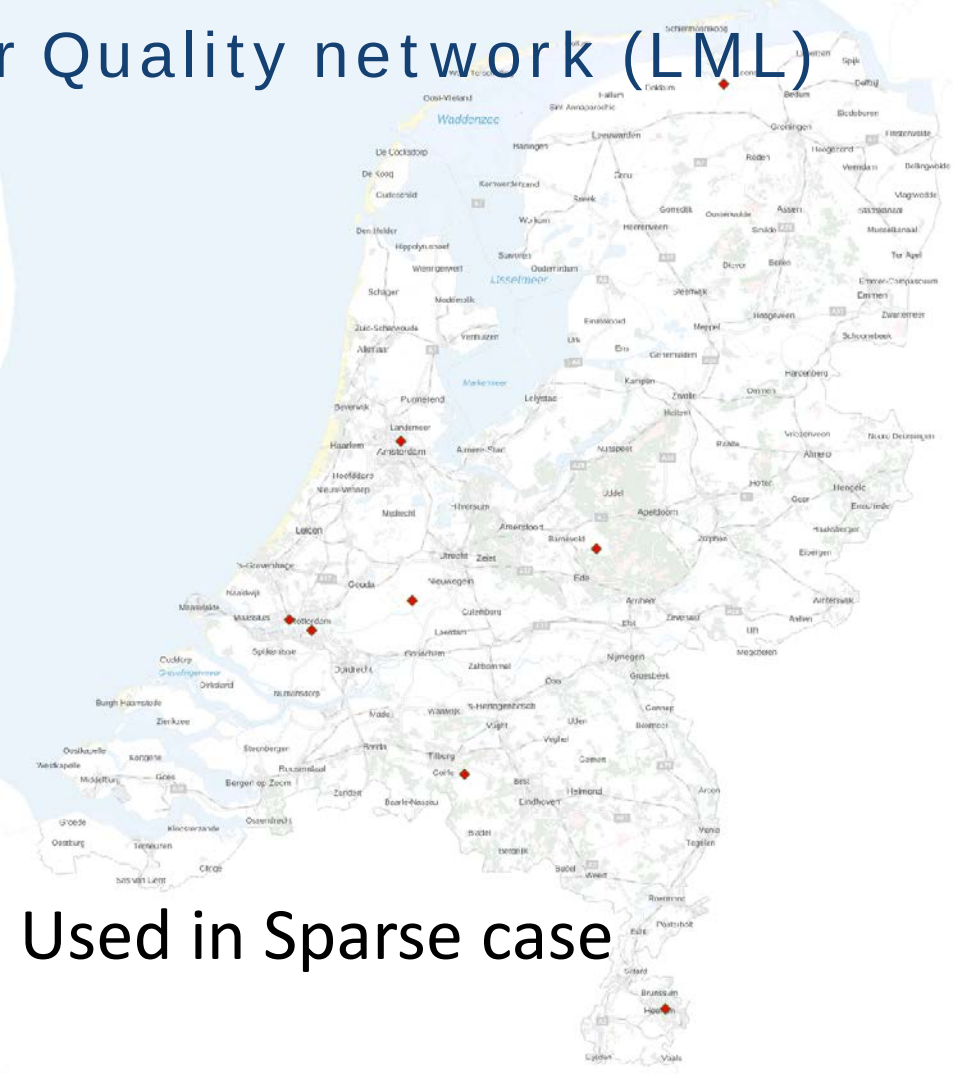
Used in base case

<u>Not</u> used in RIO

Locations National Air Quality network (LML)



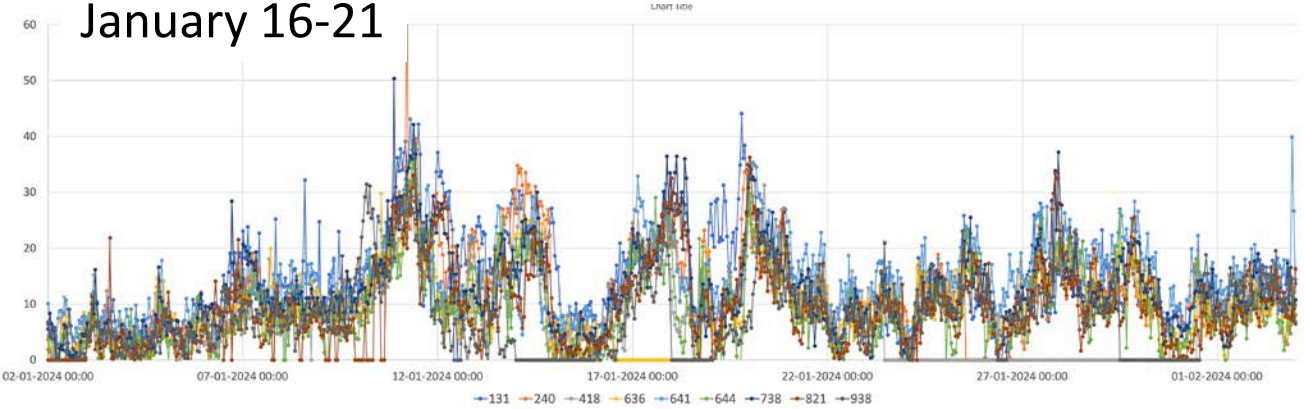
Used in MidOut case



Used in Sparse case

Interesting periods

January 16-21



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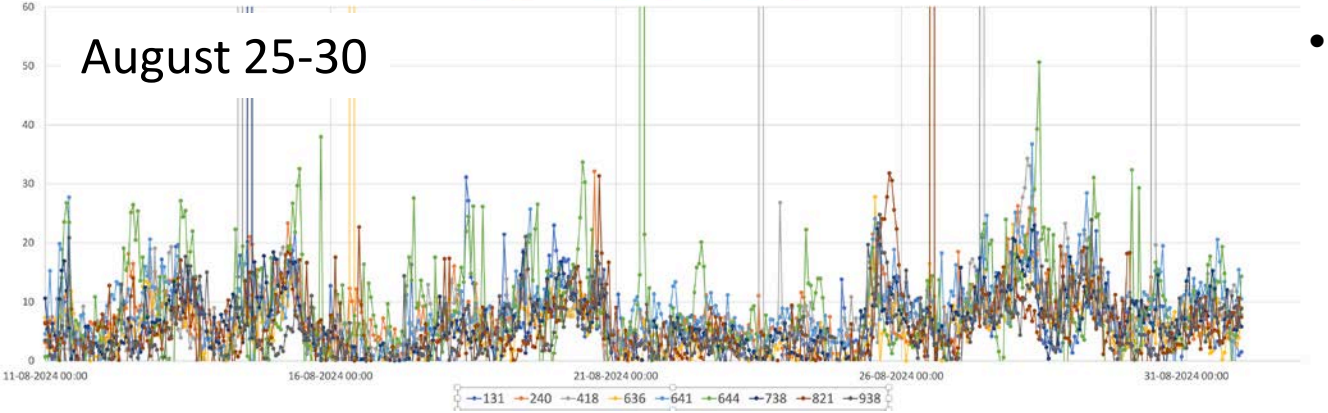


- PM2.5 concentrations at various locations spread over the country.
- Most other days in the period Jan-Sep, 2024 show low concentrations and little variations.
- Two weeks were chosen to test and compare the data fusion methods.

Input data

For every hour in the test periods, RIVM provided several files:

2024032909_official.txt	Official network	ID X Y PM2.5
2024032909_sensors.txt	Sensor data	ID X Y CALIB Ucal Urnd
2024032909_knmi.txt	Meteo data	(description follows)
2024032909_pm25_uur_11.txt	Output of RIO model	X Y CONC
2024032909_pm25_uur_11_err.txt	Uncertainty of RIO model	X Y CONC

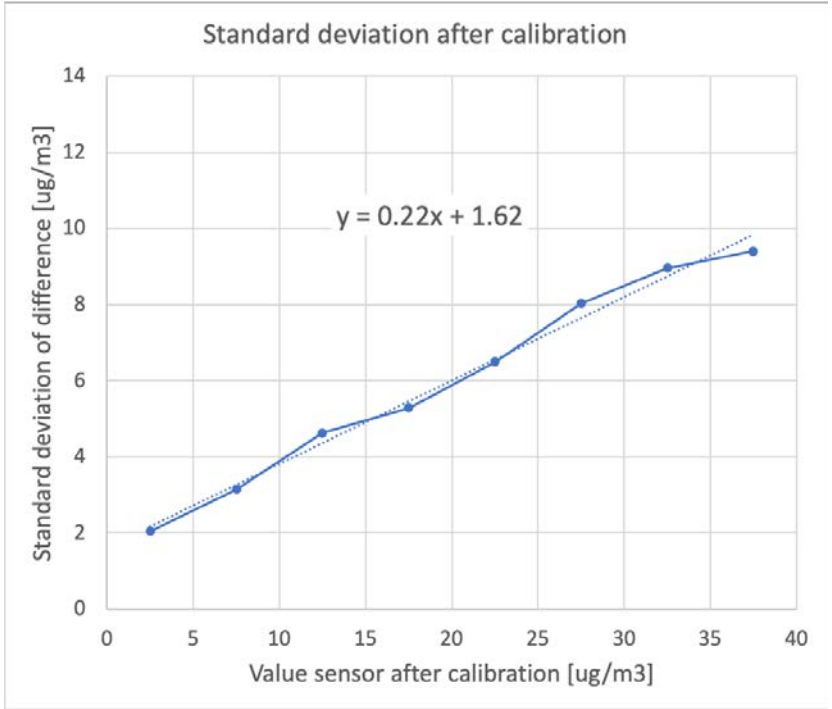
ID : Name of location or sensor
X, Y : Official Dutch coordinates, “Amersfoort /RD New”, EPSG:28992
CALIB : Calibrated Nova/SDS011 sensor data for PM2.5
Ucal : Calibration uncertainty from bootstrap
Urnd : Random uncertainty estimated from comparison to official data
CONC : RIO concentration and uncertainties

Calibration uncertainty sensors

- The calibration of the sensors is determined by comparing the average values of groups of sensors to those of neighbouring official measurements . By performing many such calibrations, each with a random selection of both available sensors and official measurements, a range of calibrated values is obtained for each sensor.

- The span of values between the 0.025 and 0.975 percentiles of the range of calibrated values is interpreted as the 95% uncertainty.

Random uncertainty sensors



- Every individual calibrated sensor has an individual random uncertainty estimated at $\sigma_{rnd,sensor}$ = 1.62 + 0.22 C ug/m3 (standard deviation), with C the calibrated concentration of the sensor.
- The uncertainty is estimated using results from many collocated sensors.

Analyze results ...

First analysis:

1. Compare the **time series** at a set of locations for the values of the RIO map and results from all the models in the benchmark.
2. Correlate model results at a set of locations with official measurements.
3. Compare average RMSE at relevant official locations that were not used in the data fusion.

Results from individual models

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Benchmark of Data Fusion using sensor data

Setup

FAIRMODE WG6, Dublin, October 8, 2024
Sjoerd van Ratingen, Joost Wesseling, RIVM

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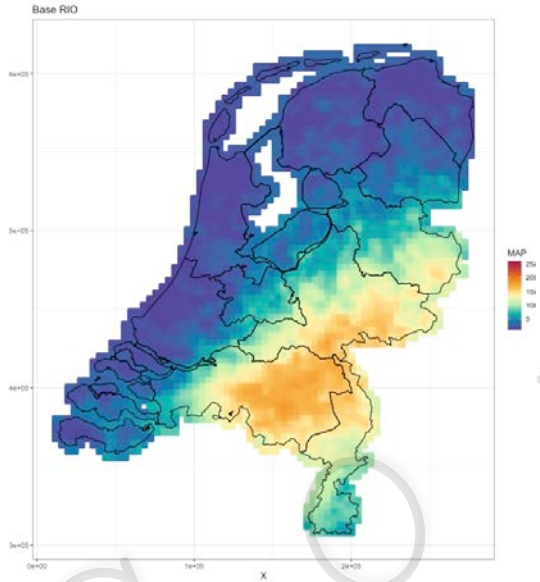
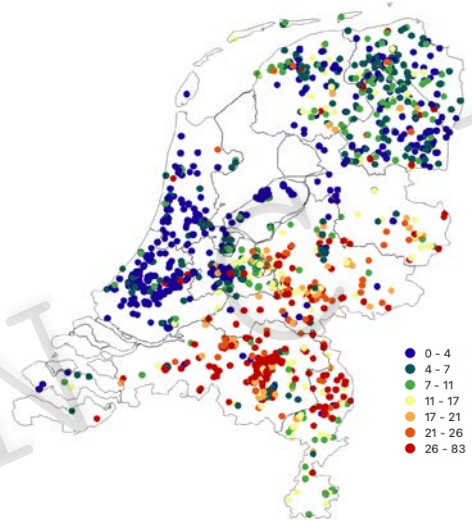
Agenda WG6 Tuesday session

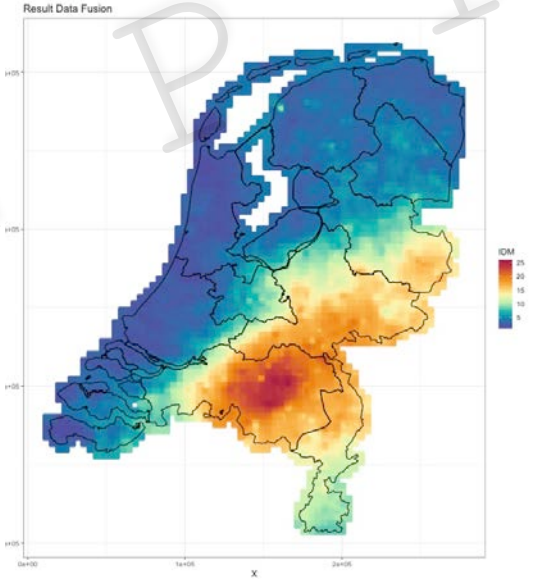
- Introduction benchmark
- Presentation of RIVM –DF results
- Comparison between preliminary results.
- Discussion/Questions

Data fusion with sensors

Starting from a concentration field based on official measurements and many sensors, what is the best combination?







CONCEPT

Analysis of 1st results Jan/Aug 2024

- Available independent official data to test the results of RIO and the data fusion.
- Interesting periods to test the data fusion.
- Six active participants have shared their model results
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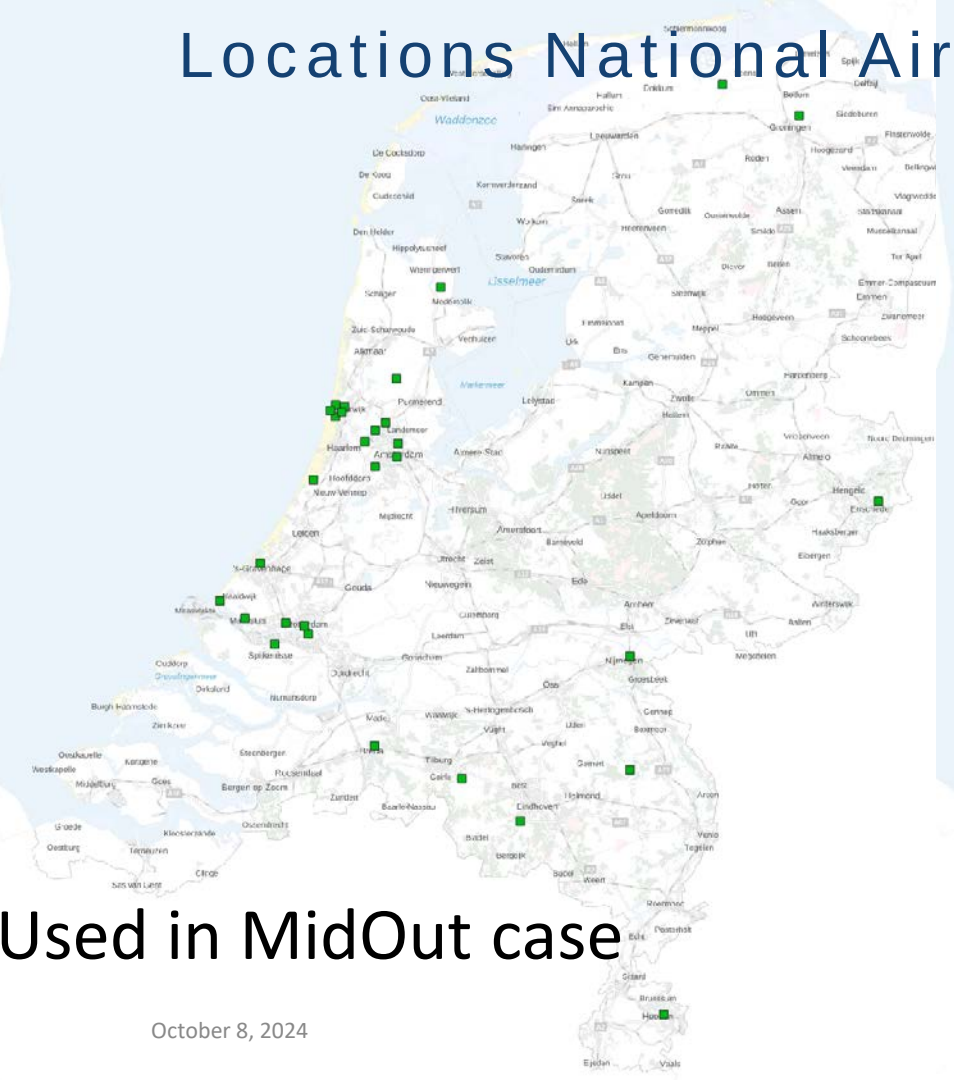

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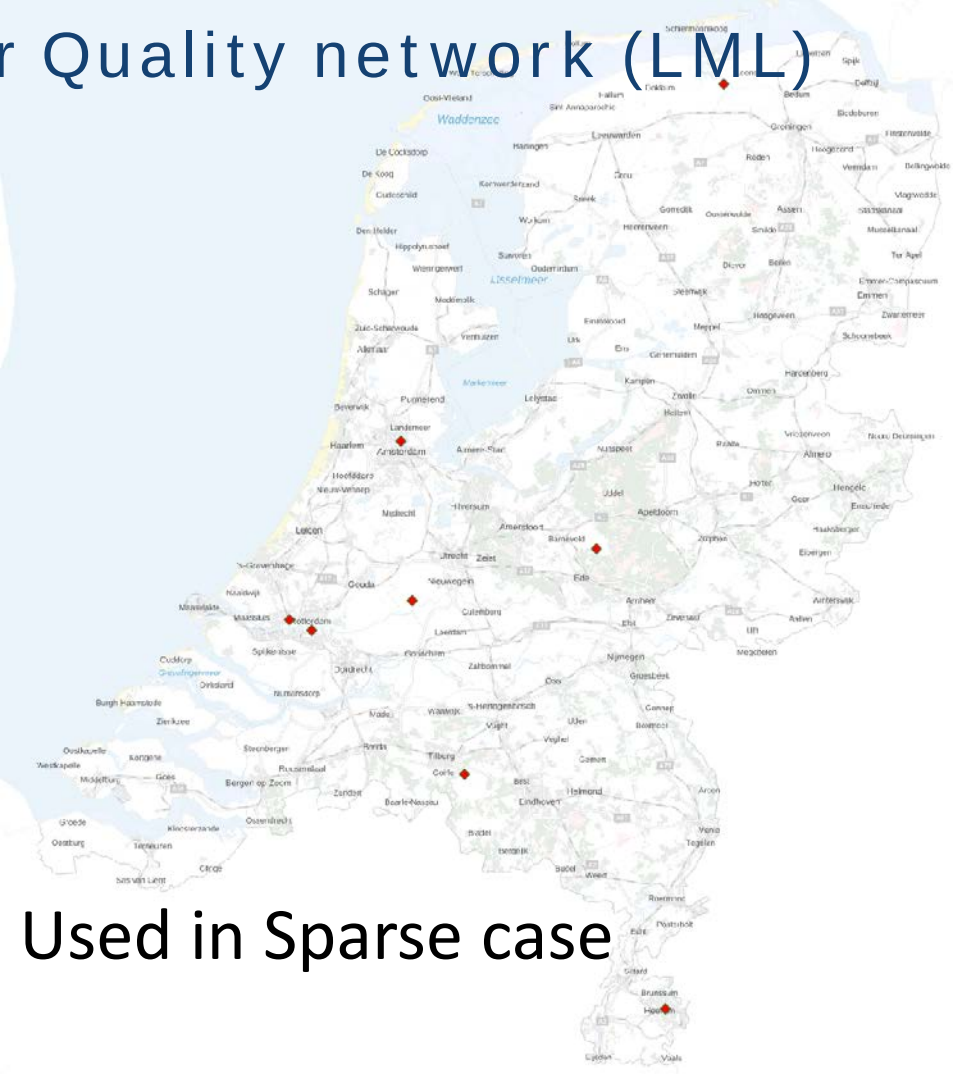

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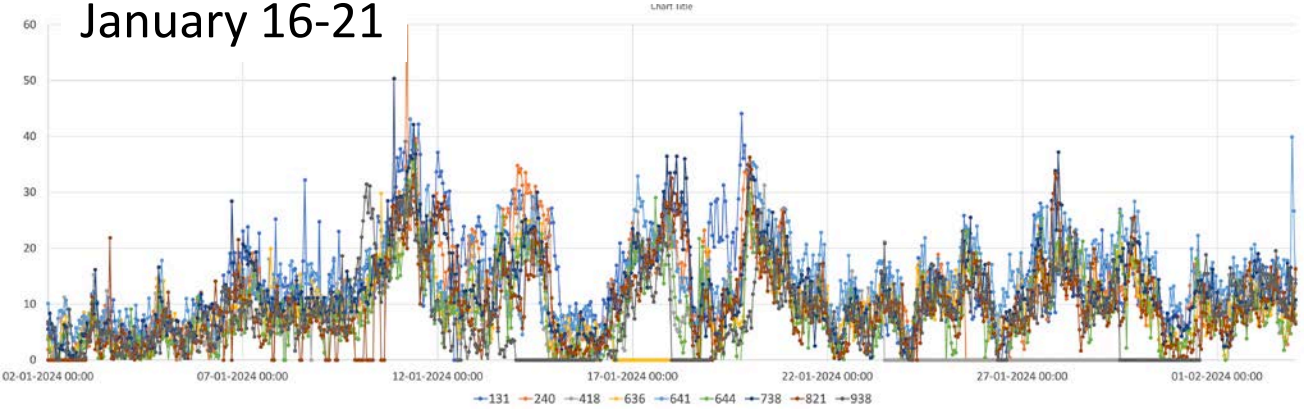

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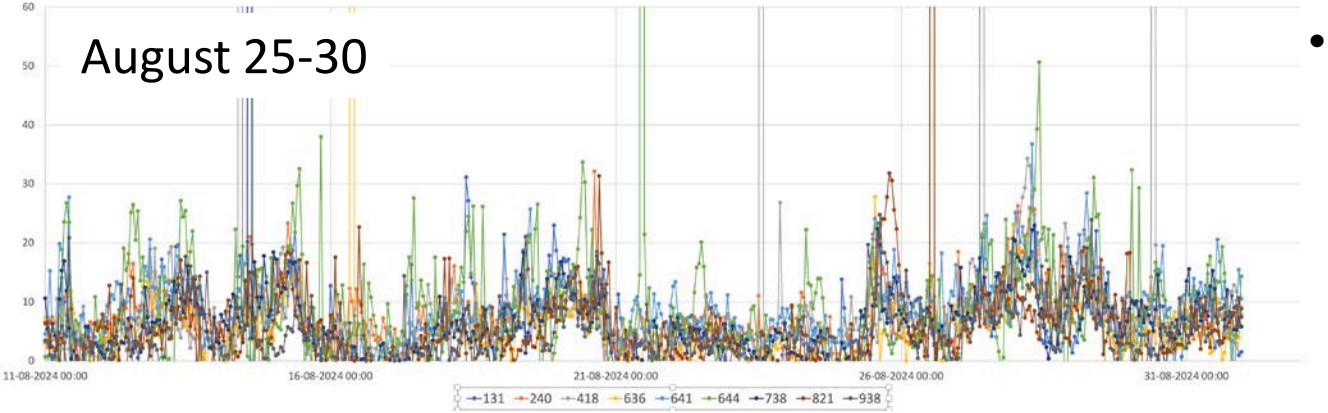

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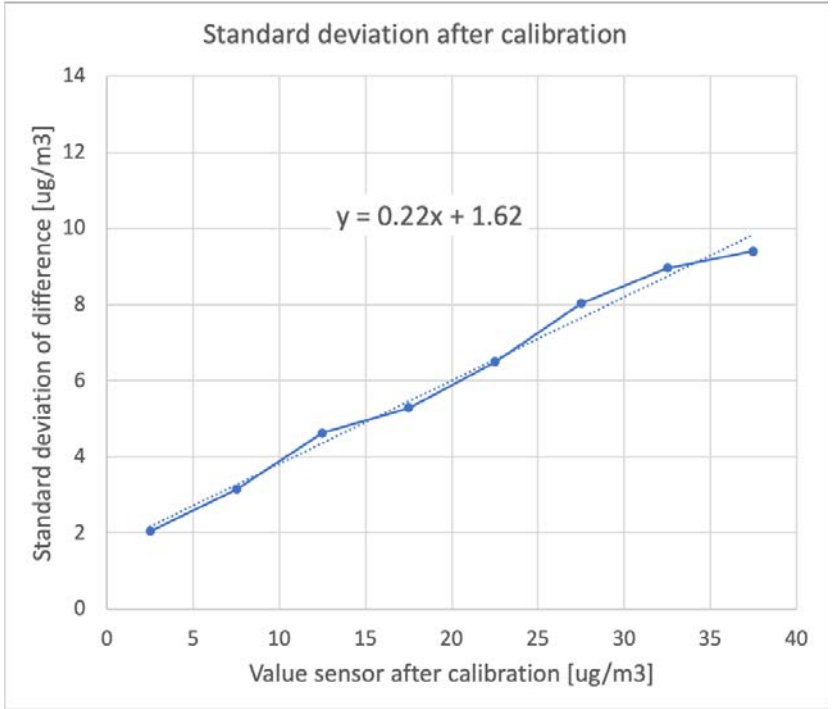

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Results from individual models

- Individual results presented Monday
  - INERIS
  - MET Norway
  - ISSep
  - CERC
  - VITO
- Individual results presented Today
  - RIVM

Analyze results ...

First analysis:

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Discussion

Are we using the best metrics for evaluating the effects of the methods

- Now: Improvement of RMSE at validation locations
- More detail: Estimate up bias and random part of RMSE?
- ……
- More focus on interesting episodes (peaks) and apply validation metrics to these situations
- Focus on metrics, fit for picking up peaks
- Focus on weak model aspects

Discussion

The RIO model that is used as a start of the DF performs already quite good. It would be interesting to use another model/map as a start, suggestions?

- CAMS(ensemble/models)
- Other variants of RIO interpolation, leaving out larger part of country
- Other countries/regions than the Netherlands?

- CAMS
- Hourly varying constant field (and estimate its uncertainty!)
- Don’t forget higher resolution than 1x1kmL
- Large variance within km cells could be indicative of local phenomena.

Discussion

Use of additional information on top of a map that is already based on these measurements?

- How would this extra information be (significantly more) useful?
- Reference stations
- Meteorological data
- Land use data

- Focus on comparing DF (per station) models that explicitly do and don’t use reference data.
- Check the effects of adding one extra reference station in an area that did not contain in.

Discussion

What practical alternatives are there for DF with sensors?

- Data assimilation ?
- DF using Machine learning ?

- DF Machine Learning , RF would be interesting to add to the benchmark

Discussion

What are the most interesting practical configurations of maps / Low Cost Sensors to test?

- Use case other than the Netherlands?

- Dense vs sparse sensor networks

- Larger vs smaller domains…

- Combining with more detailed models?
- Croatia (sparse sensornetwork), Ireland (more dense, raw measurements present?)

- Romania → Urban areas with approx. 400 sensor and 8.b. Boekarest.
- Maybe use (few) CAMS cells covering urban area as starting point construct a refined grid only using sensors.
- Consider having specific sensors for e.g. wood burning..

Discussion

Can real time sensor data be used to adjust air quality forecasts?

- Together with a meteo-forecast?
- Extrapolate corrections into next 2 -3 days ?
- Yes. Use them to correct current hour → persistence model.

Discussion

Best combinations for reference / maps / Low Cost Sensors / … ?

- Sensors still added value ?
- Which typical locations ?
- Optional ?