Near real time assessment with low-cost sensors (FAIRMODE CT6)

Proposal for benchmarking

ISSeP – 03-06-2021

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1. ISSeP strategy for benchmarking
2. Conditions of IOTs selection and evaluation of correcting models parameters
3. Results concerning correcting models parameters
4. Results concerning models application to IOTs data and production of PMx interpolated fields
5. Conclusions

1. ISSeP benchmarking strategy

1. Low-cost sensors net deployed over Netherlands territory is split throughout **IOT units** and **technical-types of sensor**.

2. Determination of **correcting parameters associated to each individual IOT/technical-type**, specifically for each observed property (presently PM_{10} and $PM_{2.5}$).

3. Correcting parameters consist in **slopes and intercepts of linear** ***y=ax+b*** **regression models**.

4. For each individual IOT/technical-type, slope and intercept are derived from **sets of coupled observed and reference values** regarding a simple *ref=A.obs+B* model.

5. Sets of coupled values are drained from **hourly measures within time-windows** extending over a sequence of few days, usually a week.

6. A **complementary environmental property**, typically RH for PMx, is used to split coupled values into sub-sets and to derive correcting parameters linked to a particular range of that complementary property.

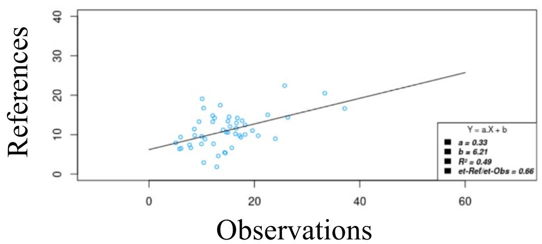
7. Reference values are obtained from **reconstructed fields produced by spatial interpolations** of measures given by RIVM telemetric stations.

1. ISSeP benchmarking strategy

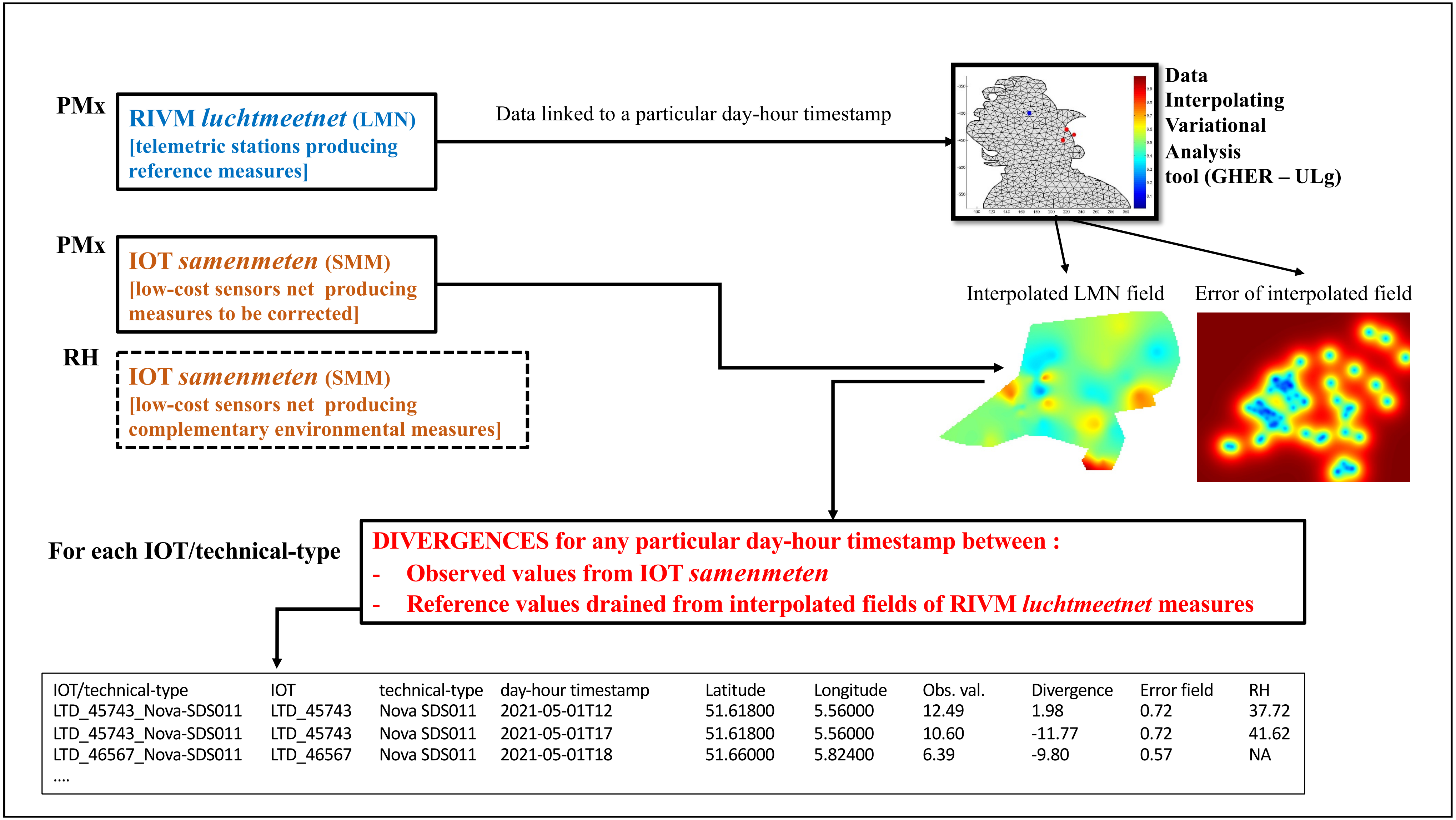
8. Each individual IOT/technical-type may participate to data fusion as far as the **error of the interpolated field of telemetric measures at its location is below a fixed limit**.

9. Measures drained from RIVM telemetric stations are only involved in the derivation of correcting parameters when their **values are above the limit of quantification of the telemetric stations devices** for the concerned PMx.

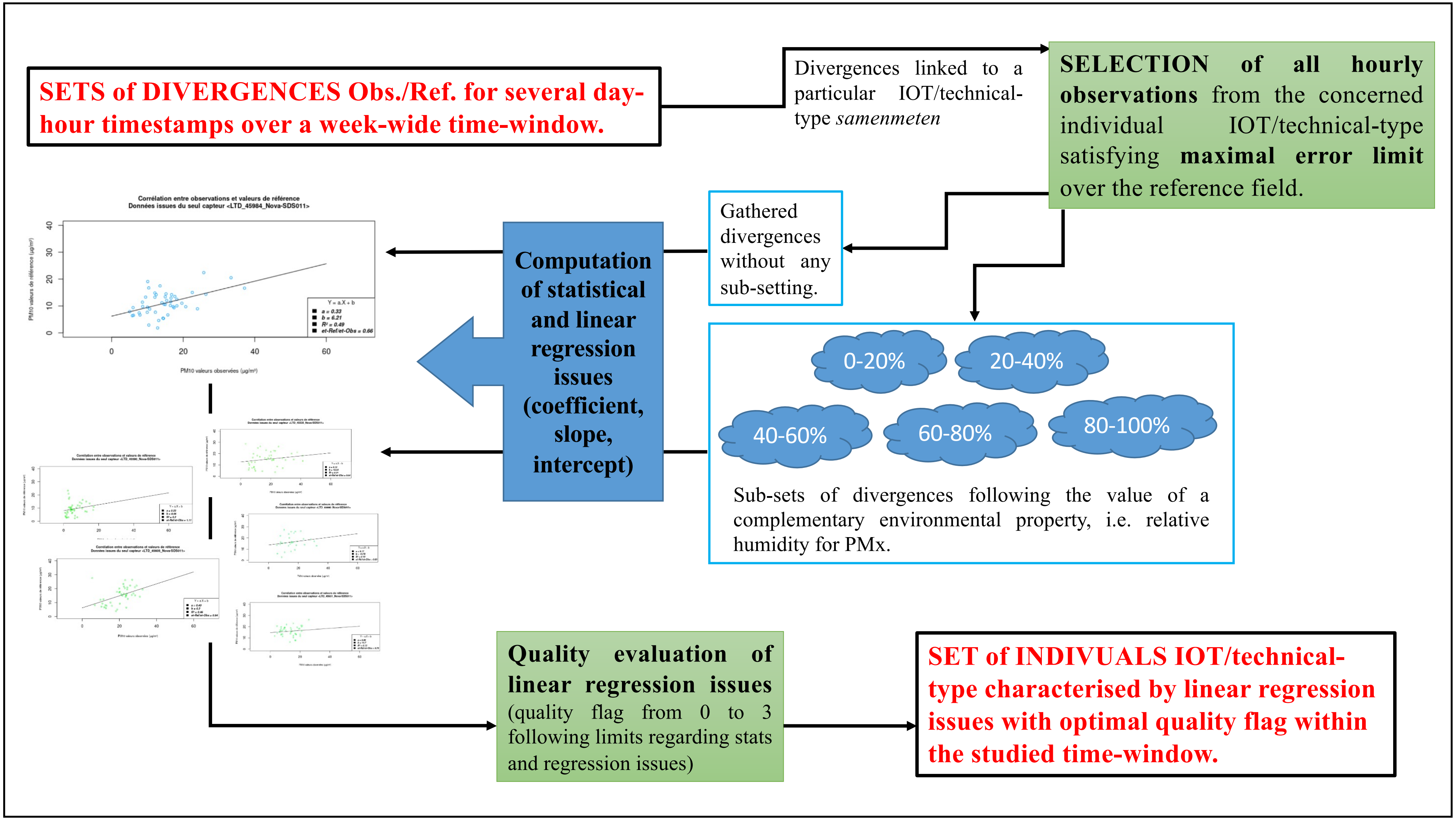
10. Correcting parameters of each selected individual IOT/technical-type support a **quality evaluation based on regression issues** (min. value for the R^2 regression coefficient, min./max. values for the regression slope, min./max. values for the ratio between standard deviation of observations and standard deviation of references).



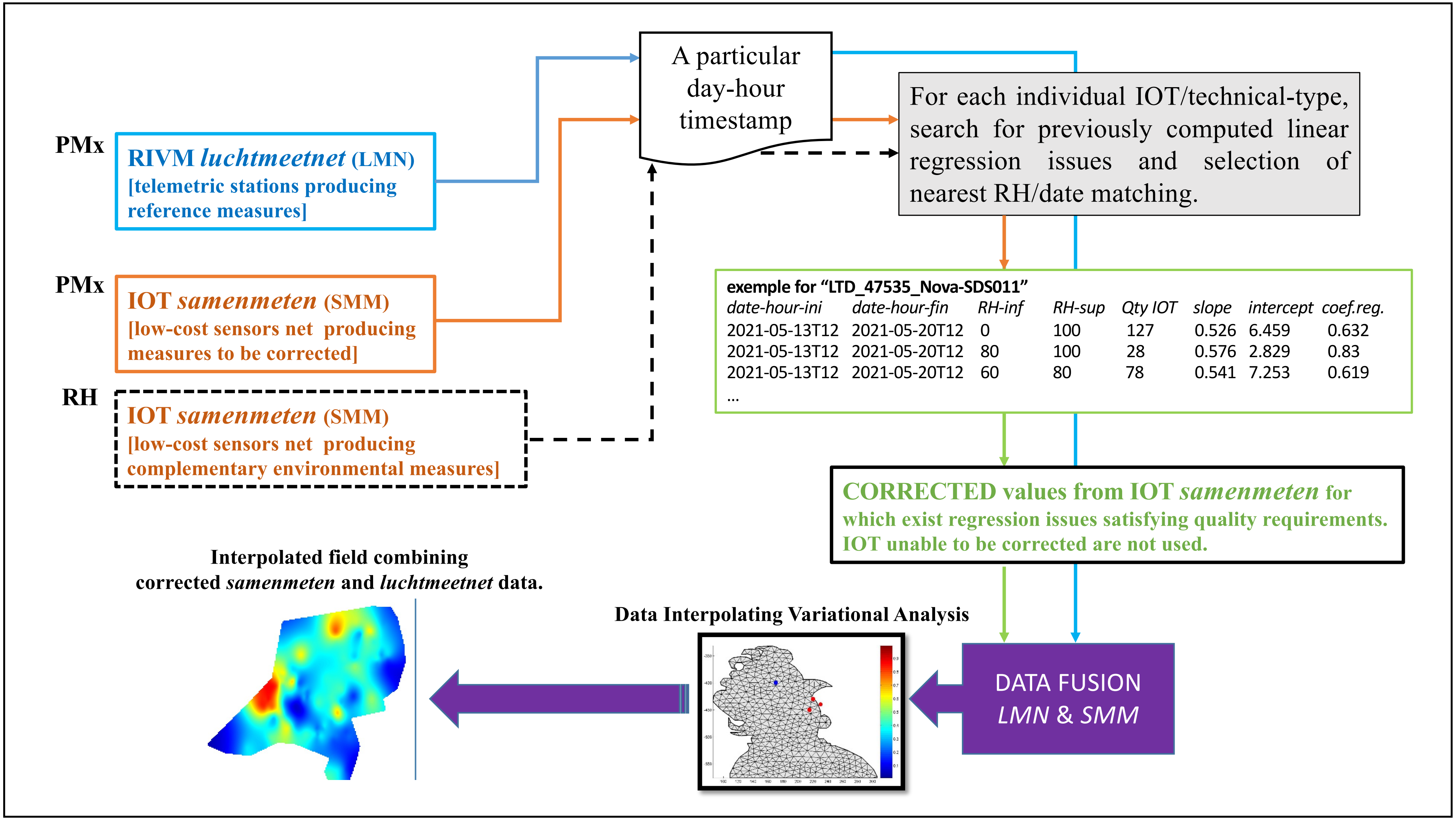
11. For any moment of interest (day-hour), **observed value from each IOT/technical-type individual is corrected regarding the availability of correcting parameters for the considered device**. Only corrected low-cost sensors data are combined to telemetric stations data. Combined data sets are used to produce final interpolated fields.



IOT/technical-type	IOT	technical-type	day-hour timestamp	Latitude	Longitude	Obs. val.	Divergence	Error field	RH
LTD_45743_Nova-SDS011	LTD_45743	Nova SDS011	2021-05-01T12	51.61800	5.56000	12.49	1.98	0.72	37.72
LTD_45743_Nova-SDS011	LTD_45743	Nova SDS011	2021-05-01T17	51.61800	5.56000	10.60	-11.77	0.72	41.62
LTD_46567_Nova-SDS011	LTD_46567	Nova SDS011	2021-05-01T18	51.66000	5.82400	6.39	-9.80	0.57	NA
....									



SETS of DIVERGENCES Obs./Ref. for several day-hour timestamps over a week-wide time-window.
Divergences linked to a particular IOT/technical-type *samenmeten*
SELECTION of all hourly observations from the concerned individual IOT/technical-type satisfying **maximal error limit** over the reference field.
Gathered divergences without any sub-setting.
Corrélation entre observations et valeurs de référence
Données issues du seul capteur <LTD_45984_Nova-SDS011>
PM10 valeurs de référence (µg/m³)
PM10 valeurs observées (µg/m³)
Y = a.X + b
a = 0.33
b = 6.21
R² = 0.49
et-Ref/et-Obs = 0.66
Computation of statistical and linear regression issues (coefficient, slope, intercept)
0-20%
20-40%
40-60%
60-80%
80-100%
Sub-sets of divergences following the value of a complementary environmental property, i.e. relative humidity for PMx.
Quality evaluation of linear regression issues (quality flag from 0 to 3 following limits regarding stats and regression issues)
SET of INDIVUALS IOT/technical-type characterised by linear regression issues with optimal quality flag within the studied time-window.


PMx
RIVM luchtmeetnet (LMN)
[telemetric stations producing reference measures]
PMx
IOT samenmeten (SMM)
[low-cost sensors net producing measures to be corrected]
RH
IOT samenmeten (SMM)
[low-cost sensors net producing complementary environmental measures]
A particular day-hour timestamp
For each individual IOT/technical-type, search for previously computed linear regression issues and selection of nearest RH/date matching.
exemple for "LTD_47535_Nova-SDS011"
date-hour-ini date-hour-fin RH-inf RH-sup Qty IOT slope intercept coef.reg.
2021-05-13T12 2021-05-20T12 0 100 127 0.526 6.459 0.632
2021-05-13T12 2021-05-20T12 80 100 28 0.576 2.829 0.83
2021-05-13T12 2021-05-20T12 60 80 78 0.541 7.253 0.619
...
CORRECTED values from IOT samenmeten for which exist regression issues satisfying quality requirements. IOT unable to be corrected are not used.
Interpolated field combining corrected samenmeten and luchtmeetnet data.
Data Interpolating Variational Analysis
DATA FUSION
LMN & SMM

2.1 Analysis of PMx data and derivation of calibrating parameters

Analysis were performed using PM_{10} / $PM_{2.5}$ *samenmeten* low-cost and *luchtmeetnet* telemetric hourly measures drained from three week-wide time-windows :

- 2021-05-**06**T12 → 2021-05-**13**T12
- 2021-05-**13**T12 → 2021-05-**20**T12
- 2021-05-**20**T12 → 2021-05-**27**T12

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- 2021-05-**20**T12 → 2021-05-**27**T12

Settings of conditions determining the selection of IOTs and the derivation of calibrating parameters :

Consideration of measures from individual IOTs regarding the **error over the *luchtmeetnet* interpolated field**
→ **max. error = 0.70**

Consideration of the minimal [PMx] values measured by telemetric stations regarding the **limit of quantification**
→ **QL = 4 µg/m³**

Consideration of **minimal quantity of data** to perform spatial interpolations as well as linear regressions
→ **at least 5 data points**

Consideration of **quality requirements regarding the linear regression issues**
→ **min. coeff. reg. (R^2) = 0.5 ; range for slope = [0.25 – 4.0] ; range for Standard Deviation ratio (ref./obs.) = [0.25 – 4.0]**

2.2 Selecting effect on *samenmeten* IOTs due to error field constrain

Limit error value fixed to 0.7 for *samenmeten* IOTs selection

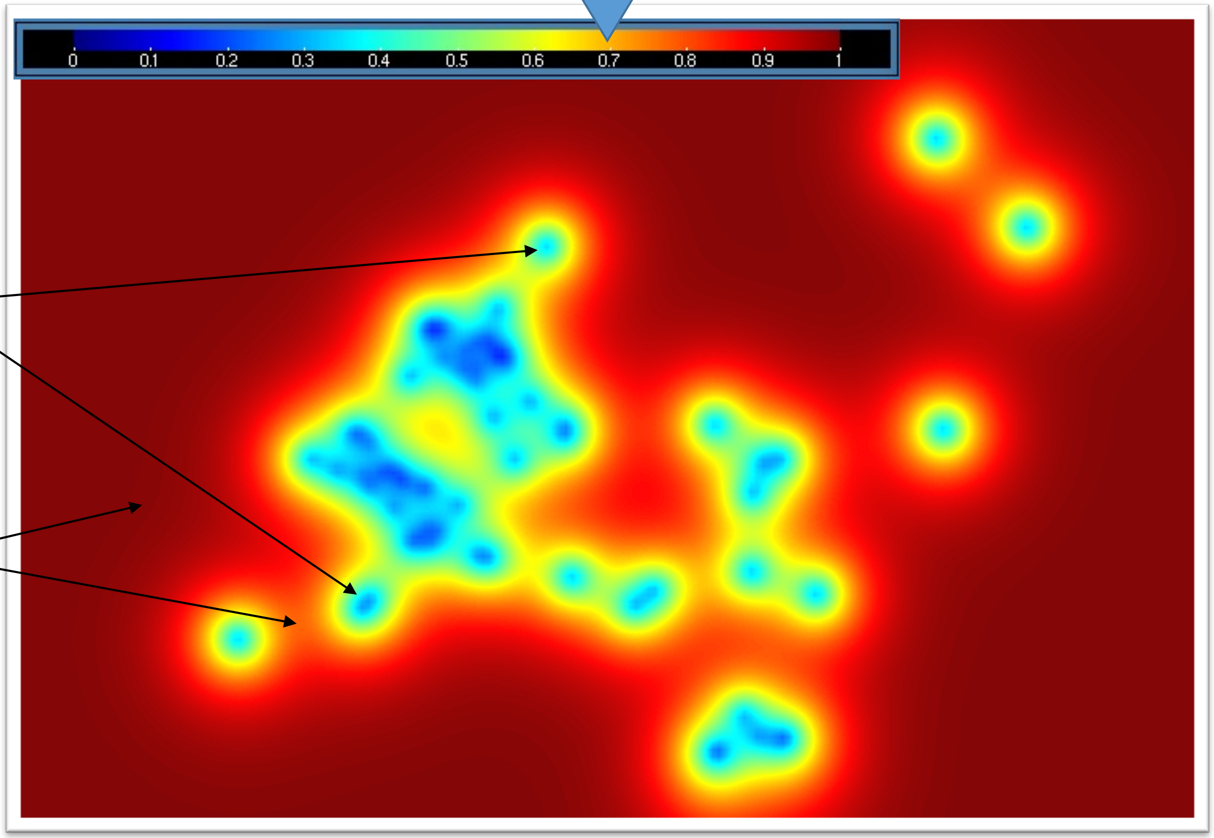


Illustration of **error field** for the spatial interpolation of **PM_{10}** measures from ***luchtmeetnet*** stations on **2021-05-16T12**.

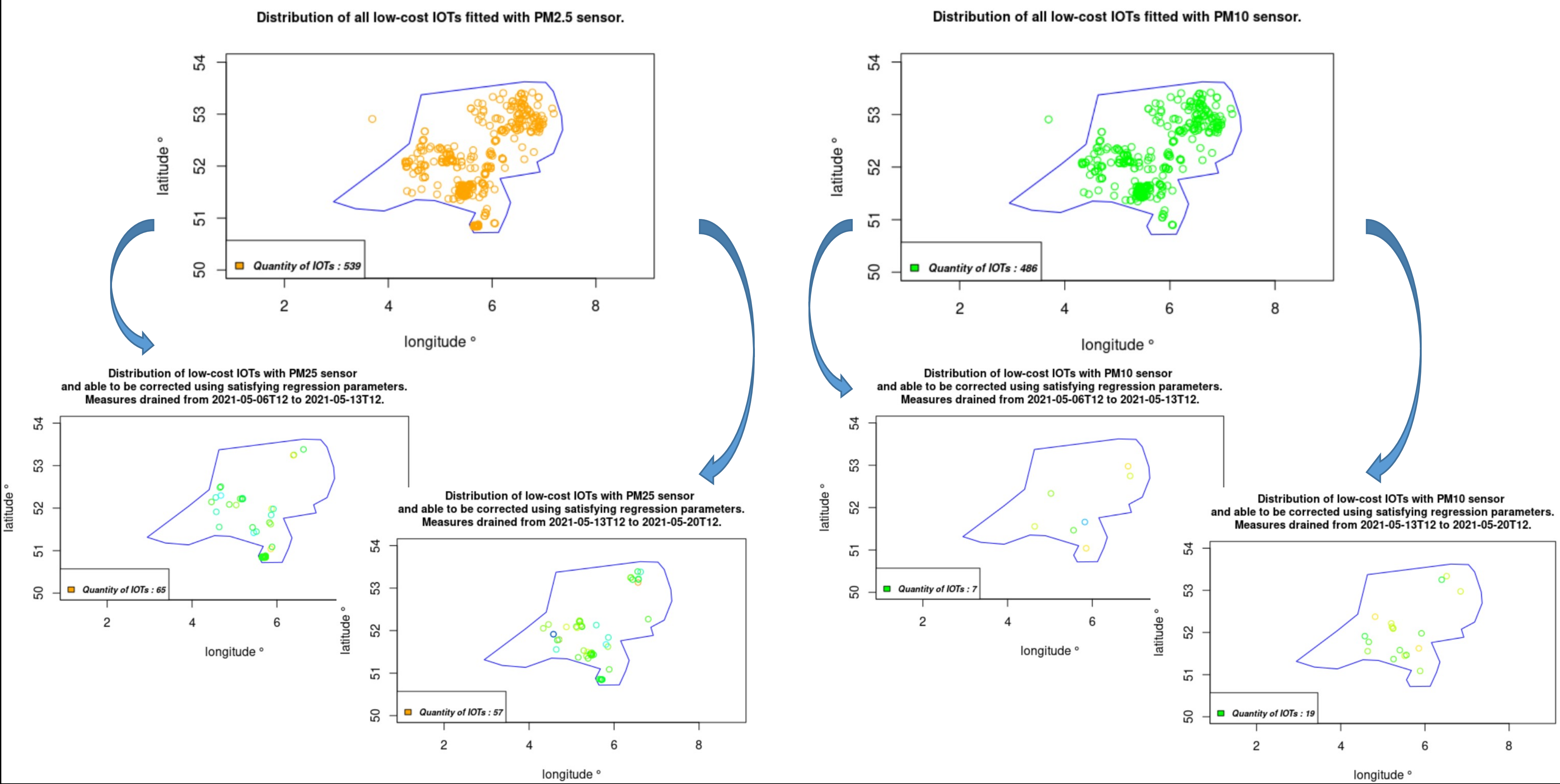
Minimal error (more or less close to 0 considering the **signal/noise ratio parameter** applied for the interpolating performance) is found on data point locations.

Maximal error (i.e. 1) is found on area excessively far from any data point, considering the collateral effect of its proper signal driven by the **correlation length parameter**.

Correlation length is set to **0.2°** (~ 22 km lat. / 14 km lon.) for all interpolating performances.

Signal to noise ratio is set to **10.0** to produce error fields and set to **7.5** to produce [PMx] analysis fields.

2.3 Distribution of *samenmeten* IOTs usable for linear regressions regarding selecting conditions



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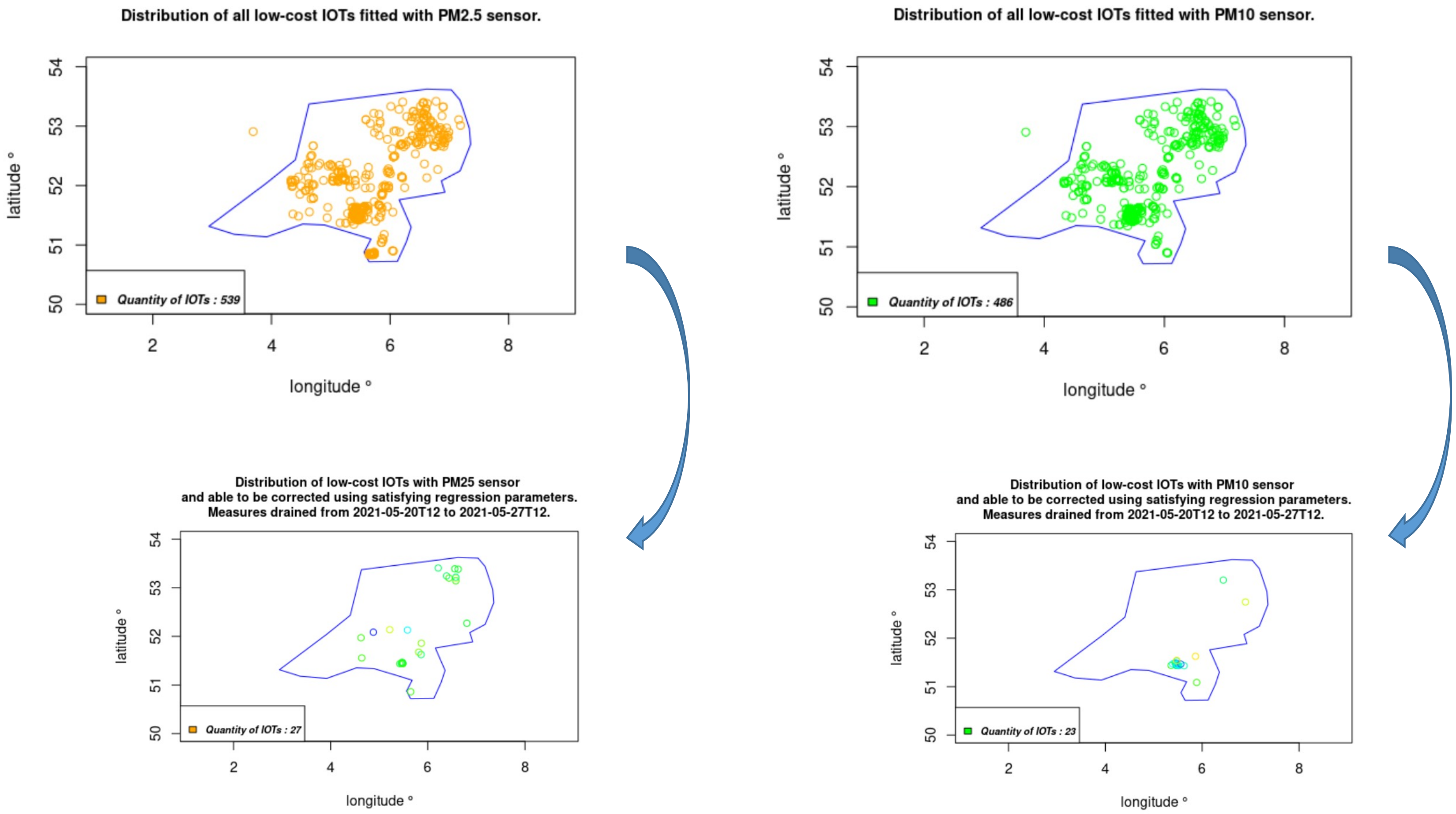


3. Results for mean slopes and intercepts of linear correcting models between observations (low-cost sensors) and references (interpolated telemetric stations)

PM2.5

```
"Time-window from 2021-05-06T12 to 2021-05-13T12 and any RH condition."
"Qty IOTs: 65 --> mean slope: 0.7~0.16 mean intercept: 3.81~1.08"
"Time-window from 2021-05-13T12 to 2021-05-20T12 and any RH condition."
"Qty IOTs: 57 --> mean slope: 0.7~0.28 mean intercept: 3.22~1.44"
"Time-window from 2021-05-20T12 to 2021-05-27T12 and any RH condition."
"Qty IOTs: 27 --> mean slope: 0.75~0.3 mean intercept: 1.21~1.72"
```

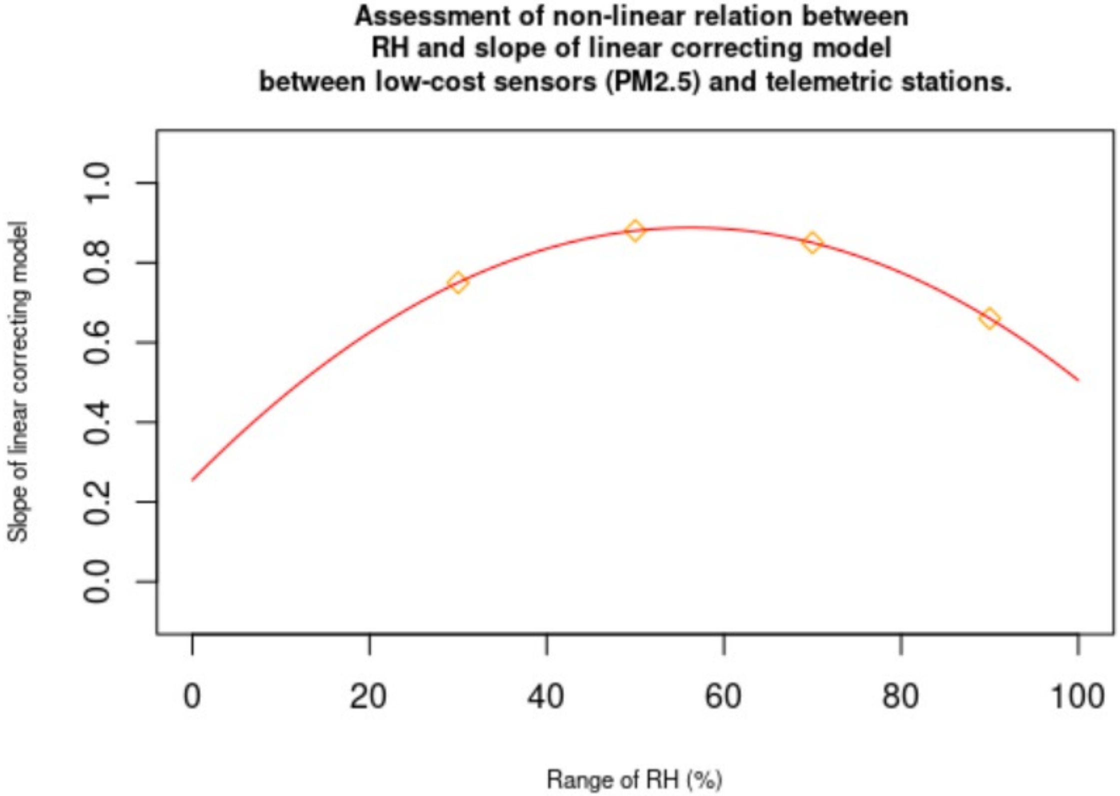
```
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 0 to 20 %"
"Qty IOTs: 0 --> mean slope: NaN~NA mean intercept: NaN~NA"
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 20 to 40 %"
"Qty IOTs: 4 --> mean slope: 0.75~0.19 mean intercept: 2.61~1.7"
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 40 to 60 %"
"Qty IOTs: 24 --> mean slope: 0.88~0.31 mean intercept: 2.21~1.89"
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 60 to 80 %"
"Qty IOTs: 40 --> mean slope: 0.85~0.41 mean intercept: 2.24~2.01"
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 80 to 100 %"
"Qty IOTs: 34 --> mean slope: 0.66~0.21 mean intercept: 2.15~1.83"
```

$[PM_{2.5}]_{corr} = \mathbf{0{,}88}.[PM_{2.5}] + \mathbf{2{,}21}$

Note: these mean slopes and intercepts are not any more linked to any particular individual IOT/technical-type.

3. Results for mean slopes and intercepts of linear correcting models between observations (low-cost sensors) and references (interpolated telemetric stations)

PM2.5



Assessment for linear correcting model of $PM_{2.5}$ low-cost IOTs measures using non-linear slope (m) determination based on relative humidity (RH).

$$[PM_{2.5}]_{corr} = \mathbf{m}.\ [PM_{2.5}] + \mathbf{2{,}2}$$

$$\mathbf{m} = a.\mathbf{RH}^2 + b.\mathbf{RH} + c$$

$a = -2.10^{-4}$
$b = 2{,}25.10^{-2}$
$c = 0{,}255$

3. Results for mean slopes and intercepts of linear correcting models between observations (low-cost sensors) and references (interpolated telemetric stations)

PM10

```
"Time-window from 2021-05-06T12 to 2021-05-13T12 and any RH condition."
"Qty IOTs: 7 --> mean slope: 0.58~0.37 mean intercept: 7.65~2.07"
"Time-window from 2021-05-13T12 to 2021-05-20T12 and any RH condition."
"Qty IOTs: 19 --> mean slope: 0.51~0.13 mean intercept: 6.15~5.42"
"Time-window from 2021-05-20T12 to 2021-05-27T12 and any RH condition."
"Qty IOTs: 23 --> mean slope: 1.02~0.37 mean intercept: 1.11~2.81"
```

```
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 0 to 20 %"
"Qty IOTs: 0 --> mean slope: NaN~NA mean intercept: NaN~NA"
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 20 to 40 %"
"Qty IOTs: 0 --> mean slope: NaN~NA mean intercept: NaN~NA"
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 40 to 60 %"
"Qty IOTs: 7 --> mean slope: 0.76~0.52 mean intercept: 6.03~4.16"
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 60 to 80 %"
"Qty IOTs: 17 --> mean slope: 0.6~0.14 mean intercept: 6.01~2.37"
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 80 to 100 %"
"Qty IOTs: 19 --> mean slope: 0.57~0.23 mean intercept: 2.35~12.76"
```

$[PM_{10}]_{corr} = \mathbf{0{,}76}.[PM_{10}] + \mathbf{6{,}03}$

Note: these mean slopes and intercepts are not any more linked to any particular individual IOT/technical-type.

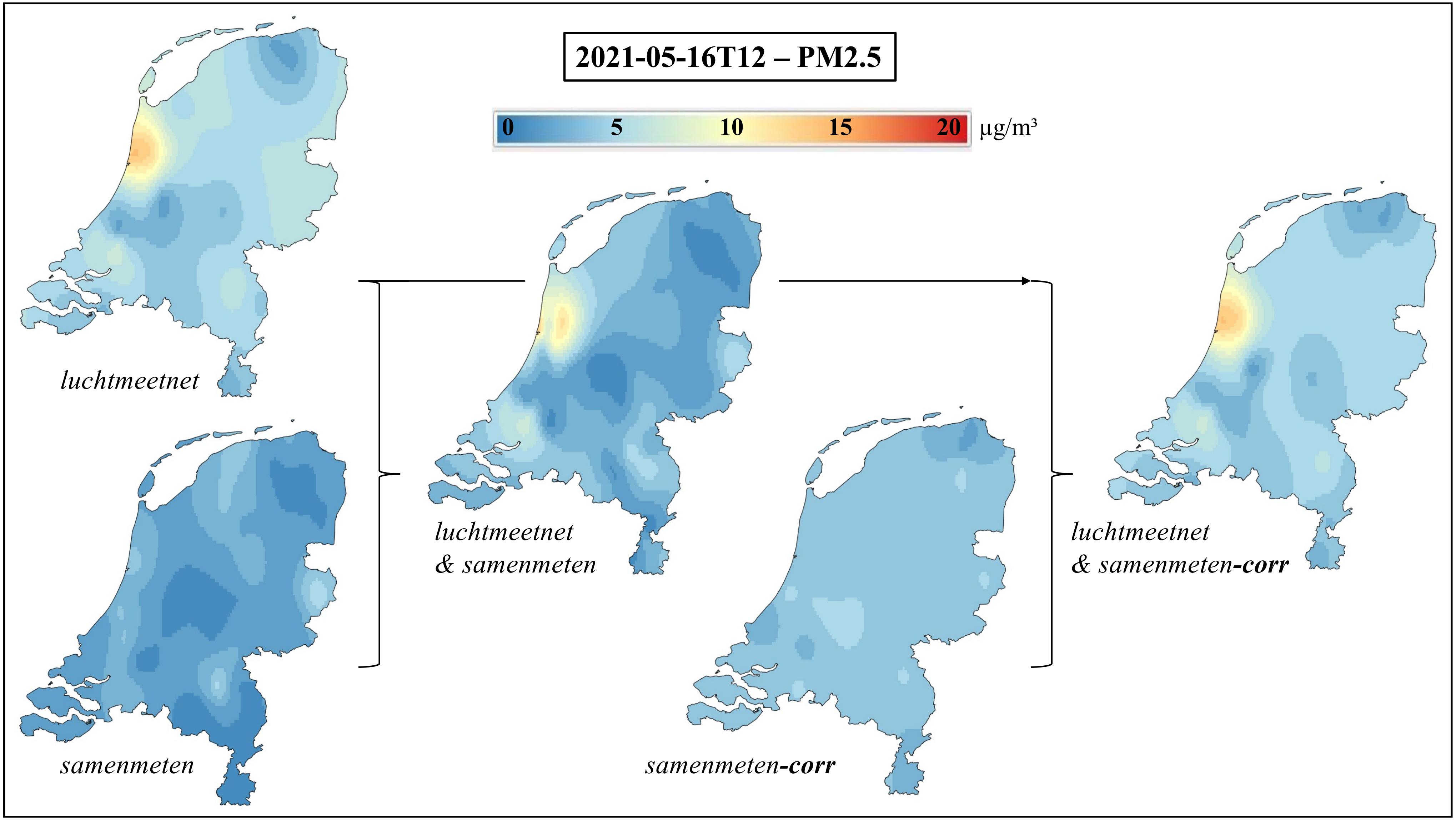
4. Results of [PMx] interpolated fields produced with *samenmeten IOTs* & *luchtmeetnet stations* combined data

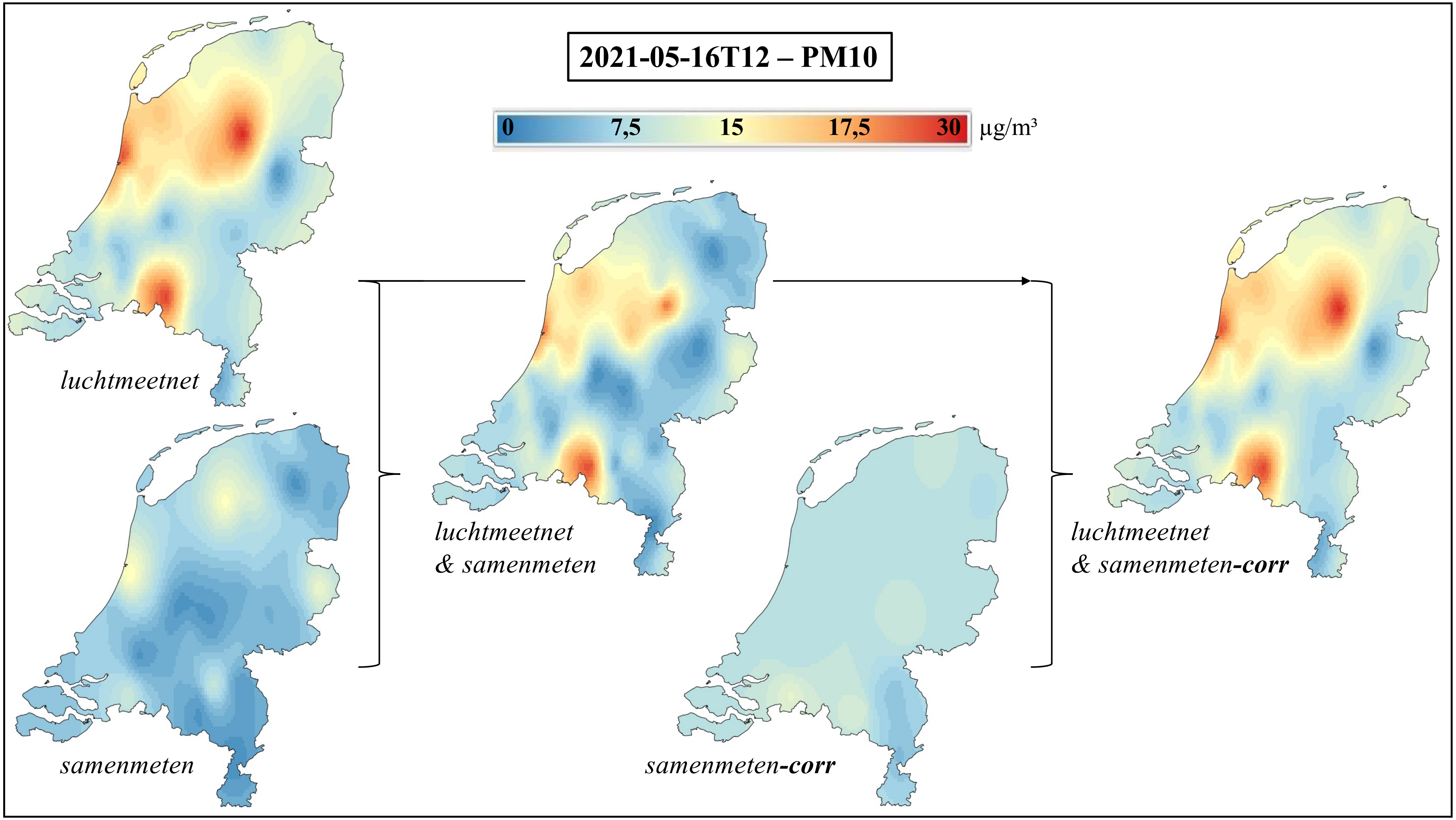
- An interpolated field uses only [PMx] data produced at a particular **day-hour timestamp**.

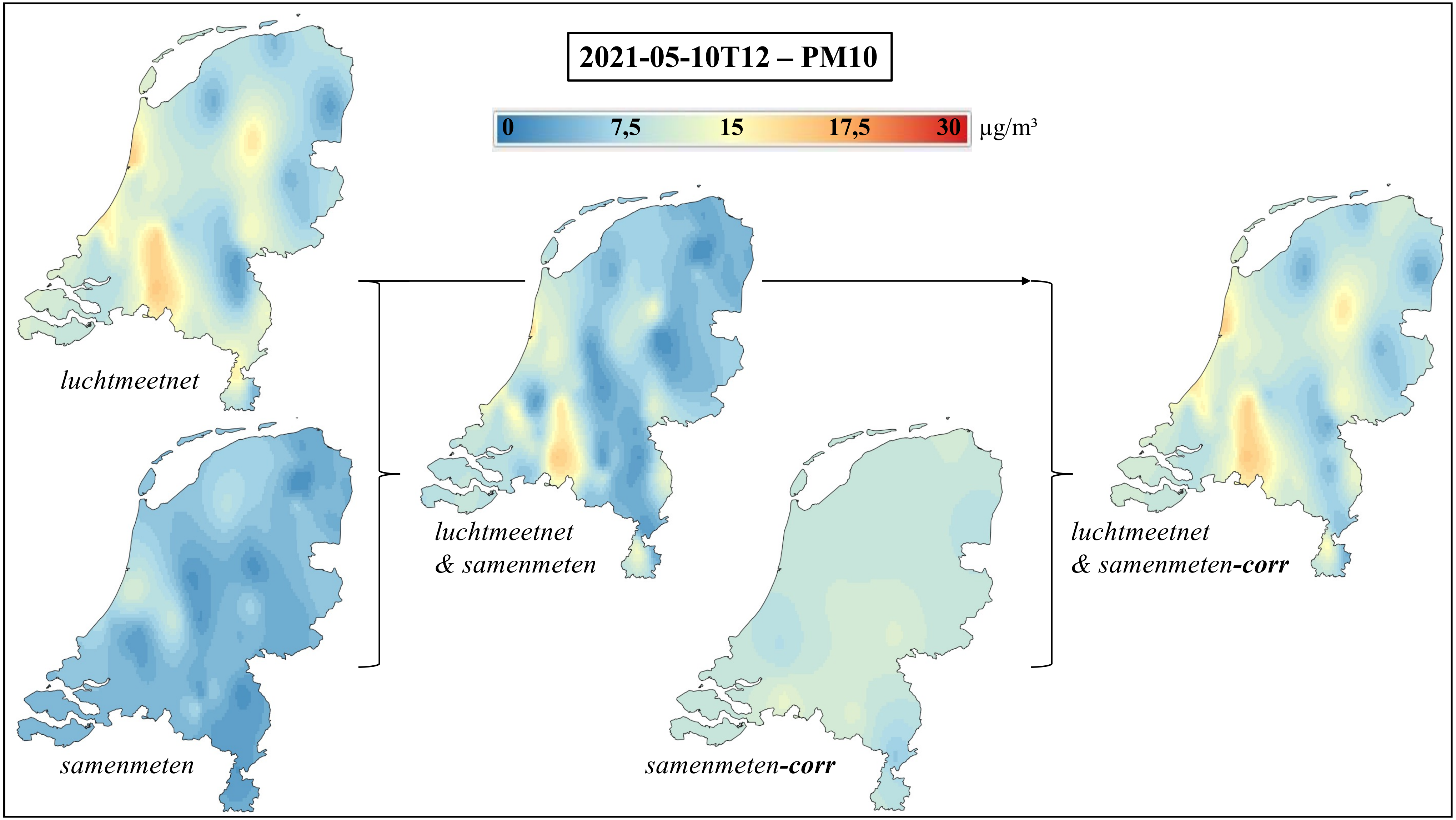
- **Only data from *samenmeten* IOTs that are able to be corrected** are involved in the data combination with *luchtmeetnet* stations data.

- Any individual IOT/technical-type is corrected with its **specific linear regression parameters** (not the mean slopes nor mean intercepts) and these parameters **fully comply with the optimal quality requirements**.

- If the PMx measure of the IOT is associated to a concomitant RH measure, that last value is used to determine the RH range and the correspondent regression parameters. **If no RH measure is available, the value of 50% is applied as RH value**.


2021-05-16T12 – PM2.5
0
5
10
15
20
µg/m³
luchtmeetnet
samenmeten
luchtmeetnet
& samenmeten
samenmeten-corr
luchtmeetnet
& samenmeten-corr


2021-05-16T12 – PM10
0
7,5
15
17,5
30
µg/m³
luchtmeetnet
samenmeten
luchtmeetnet
& samenmeten
samenmeten-corr
luchtmeetnet
& samenmeten-corr


2021-05-10T12 – PM10
0
7,5
15
17,5
30
µg/m³
luchtmeetnet
samenmeten
luchtmeetnet
& samenmeten
samenmeten-corr
luchtmeetnet
& samenmeten-corr

5. Conclusions

- The fields constructed with **the only *samenmeten* IOTs uncorrected data display globally lower values**, in contrast to the fields constructed with the *luchtmeetnet* data.

- The correction of the *samenmeten* IOTs data tends to lower the native values due to the correcting models slopes below 1 but an **increasing correcting effect is observed in case of weak PMx concentrations** due to the models intercepts whose values are ranging from 2 up to 10 µg/m³.

- The **maximal acceptable value for the error field is a determinant parameter** due to its direct impact on the *samenmeten* IOTs selection. **Consequently, combined data fields appear very similar to only *luchtmeetnet* data fields** due to, on the one hand, the elimination of *samenmeten* IOTs too far from telemetric stations, and on the other hand, the correction of *samenmeten* IOTs data using linear models parametrised by the divergences between those close telemetric stations and selected IOTs.

- High quality requirements (selection of IOTs as well as regression issues) applied for the parametrisation of correcting models permitted to assess the **relation between relative humidity and the slopes of these correcting linear models**.

- Reliable correcting linear models parameters, eventually driven by relative humidity level, should be **derived correspondently to any technical-type of IOTs**. Thereafter, these correcting models may be **applied to *samenmeten* IOTs disregarding their proximity to telemetric stations** under the condition of prior check using a **complementary *samenmeten* IOTs measure (e.g. temperature) assuring that IOTs are properly deployed outdoor**.