FAIRMODE TECHNICAL MEETING
06 – 08 October 2021

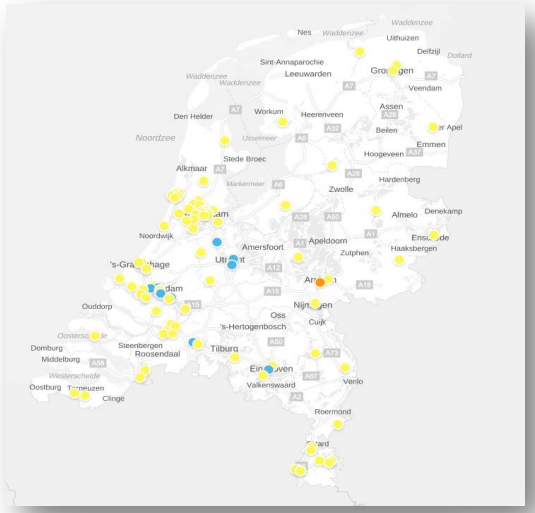
Near real time assessment with low-cost sensors (FAIRMODE CT6)

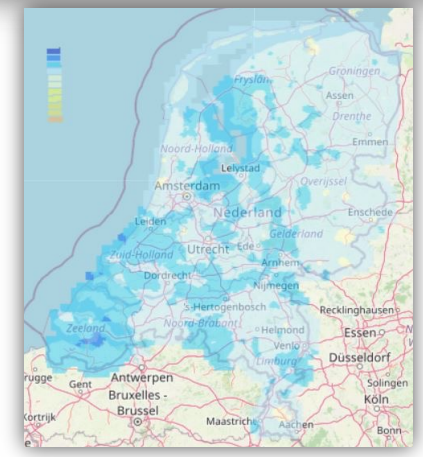
Proposal for benchmarking

ISSeP
Institut Scientifique de Service Public
(Belgique)

Dutch RIVM fixed telemetric stations

(src. RIVM - https://www.luchtmeetnet.nl/)

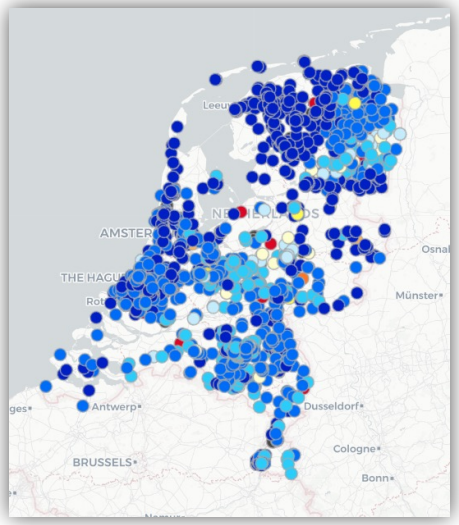


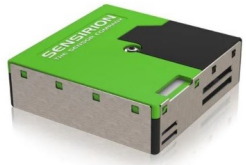


DATA FUSION

Low-cost sensors net deployed over The Netherlands

(src. RIVM - https://sensors.rivm.nl/dataportaal/)





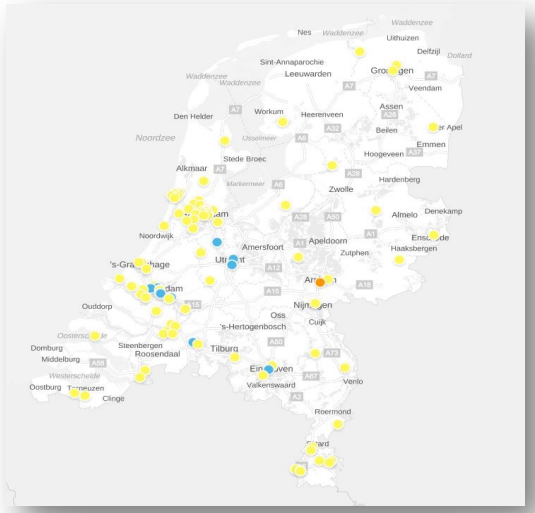
Outliers detection and removal

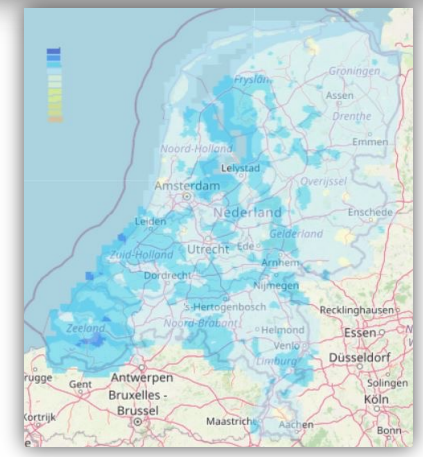
Raw values correction with calibrated model

Data merging from telemetric stations and low-cost sensors

Merged data **spatial interpolation** into continuous field

RIVM fixed telemetric stations
(src. RIVM - https://www.luchtmeetnet.nl/)





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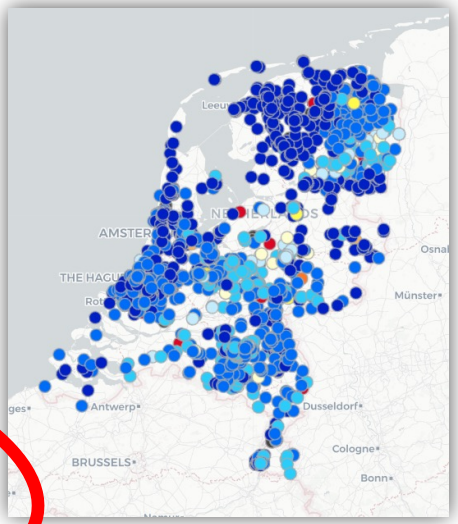
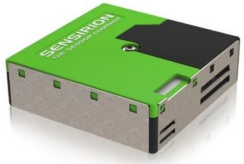




Outliers detection and removal

Raw values correction with calibrated linear model

Data merging from telemetric stations and low-cost sensors

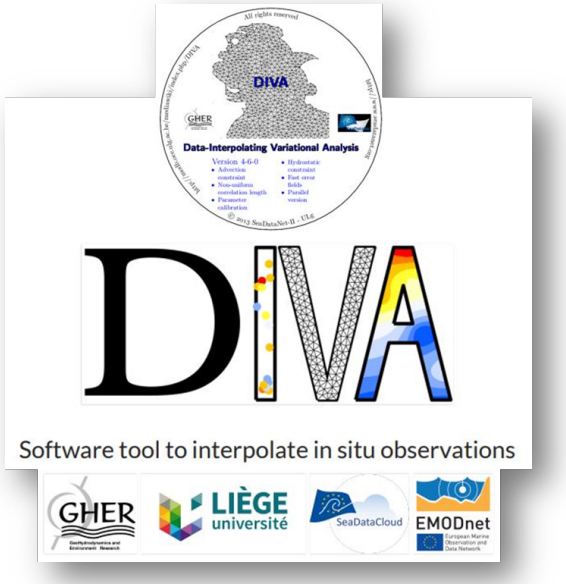
Merged data **spatial interpolation** into continuous field

Calibration of linear correcting models for low-cost sensors

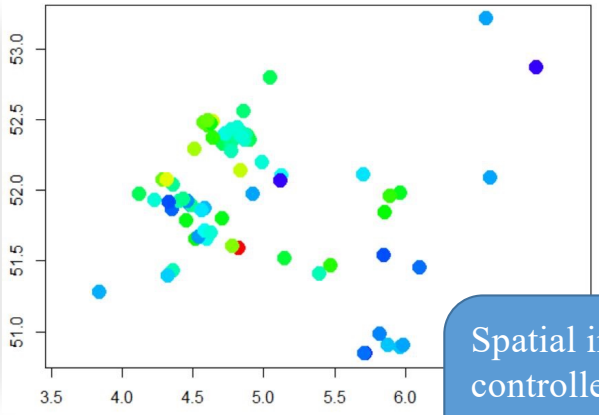
$$corr. = \alpha \times raw + \beta$$

- Correcting parameters (slope α and intercept β) are derived by **linear regression for each individual low-cost sensor**
- Linear regressions are based on **concomitant-colocated reference and low-cost sensor values** sampled from a defined time-window
- References values are drawn from a reconstructed field of the studied environmental property (i.e. **[PMx]**) provided by a **spatial interpolating tool** (cfr. **DIVA** tool).
- Interpolated fields are produced using telemetric stations measurements and are associated to **interpolation error fields**
- Low-cost sensors are evaluated regarding the **relevance of their calibrations** :
  → removal of sensors located in areas where interpolation error exceeds a defined limit
  → removal of sensors for which α and β over-range limits reflecting correct deployment of the sensor device
- **Dependence between calibration of sensors and environmental conditions** is assessed using a complementary sub-setting of sampled low-cost sensor values regarding the relative humidity level

Production of spatial interpolated fields from reference measurements
Application of DIVA interpolating tool

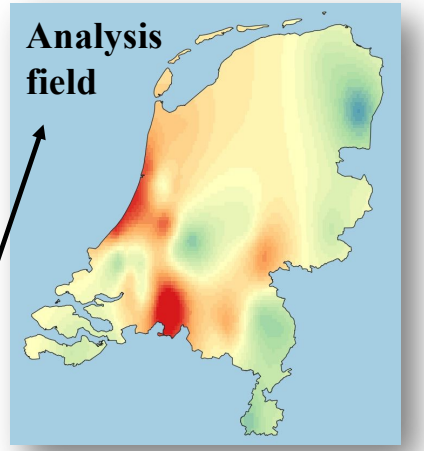


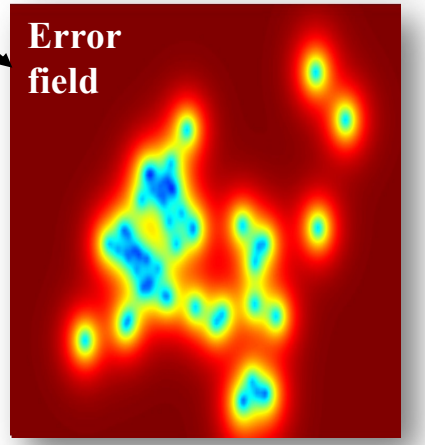
Distribution of data points



Spatial interpolation controlled mainly by :

- **correlation length**
- **signal to noise ratio**

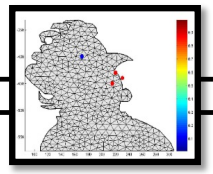




Main features of DIVA :

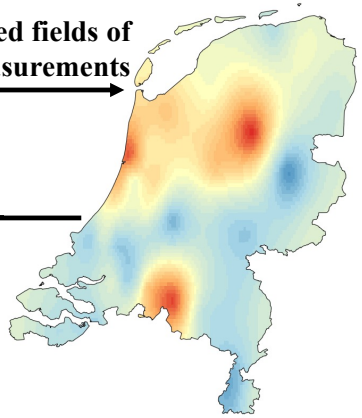
- interpolates irregularly-spaced and noisy values from large data sets
- uses a finite-element solver
- minimises a cost-function penalizing misfit between observations and interpolated field
- takes into account topographic and dynamic constraints such as wind advection
- produces an error field which is based on a real covariance function

REFERENCE measurements for **PMx** → **from RIVM telemetric stations**

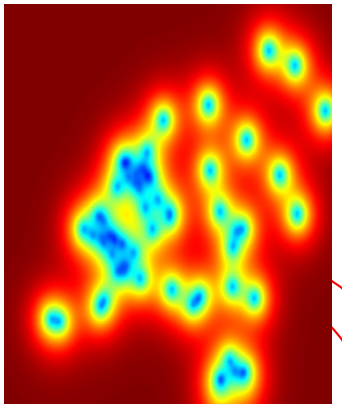


DIVA analysis

Interpolated fields of reference measurements



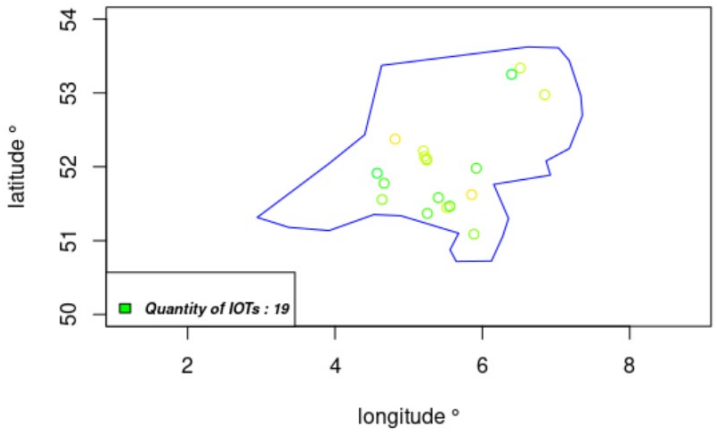
Error field associated to each interpolated reference field



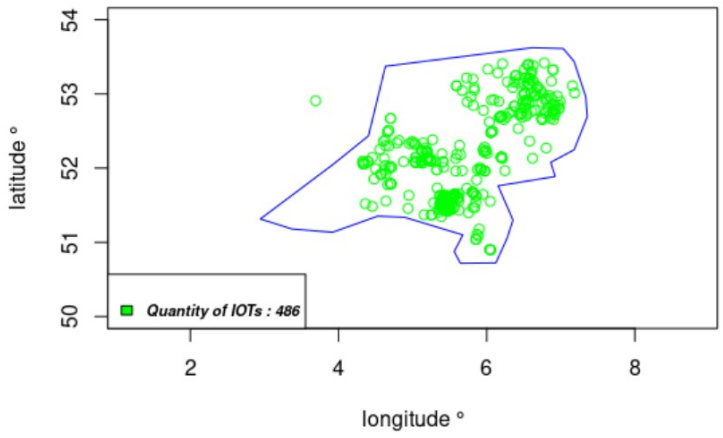
TO BE CORRECTED measurements for **PMx** → **from low-cost sensors net**

Selection of low-cost sensors within areas below a maximal error for the reference interpolated field

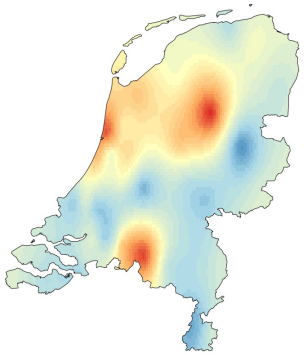
Distribution of low-cost sensors able to be calibrated regarding the maximal tolerable interpolation error



Distribution of all low-cost IOTs fitted with PM10 sensor.

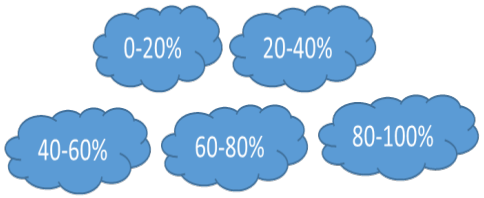


A 10 days sampling of hourly measurements provides ~ 240 values reference/low-cost



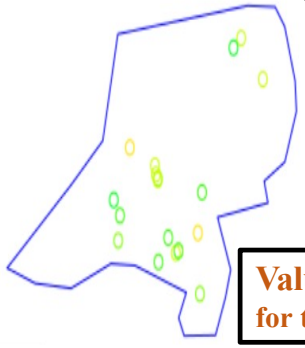
Interpolated field of reference values,
for a particular day-hour timestamp

DEVIATIONS for any timestamp between :
- **reference values**
- **low-cost values**



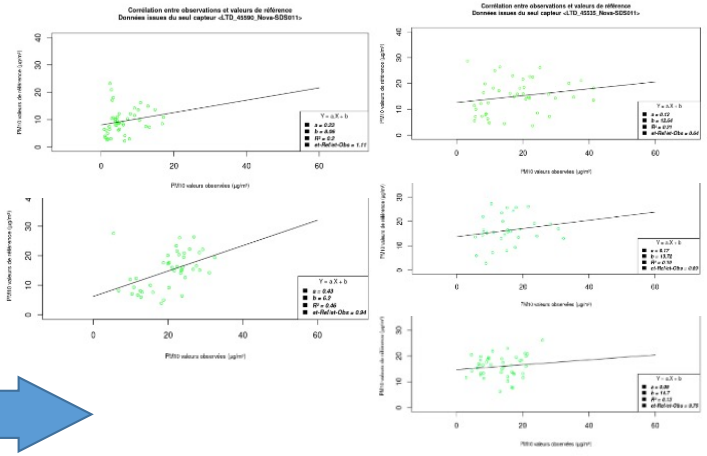
Sub-sets of [PMx] deviations following concomitant/collocated **relative humidity measures** for each [PMx] low-cost value

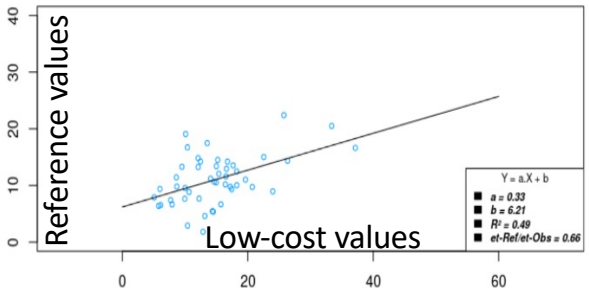
complementary measurements of **RELATIVE HUMIDITY**
→ **from low-cost sensors net**



Values from low-cost sensors able to be calibrated,
for the same day-hour timestamp

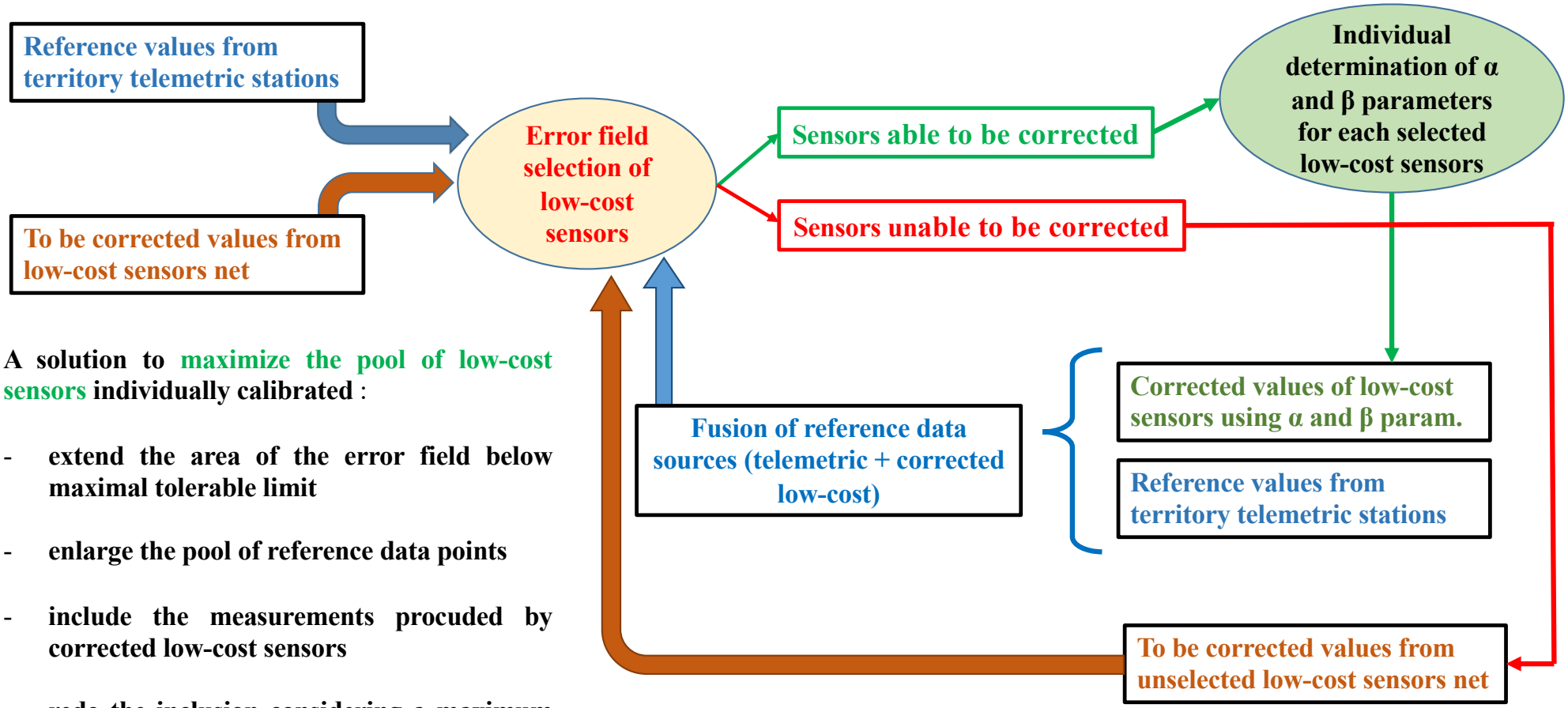
Computation of linear regression parameters (coefficient, slope, intercept)





Quality evaluation of linear regression issues
Second selection of low-cost sensors regarding quality criteria for linear regression parameters (R^2 - min./max. slope – min./max. SD ratio between reference and low-cost values)

Possibility of an iterative approach as a complement to base strategy



A solution to maximize the pool of low-cost sensors individually calibrated :

- **extend the area of the error field below maximal tolerable limit**
- **enlarge the pool of reference data points**
- **include the measurements procuded by corrected low-cost sensors**
- **redo the inclusion considering a maximum of 3 iterations withstanding the gain of calibration uncertainty**

Global strategy for calibration of sensors and correction of data

Territory telemetric stations

Low-cost sensors net

Part of low-cost sensors able to be individually calibrated → **Application of SPECIFIC α and β correcting parameters**

Part of low-cost sensors out of range for individual calibrations → application of a "blind" correction → **Check for outliers and abnormal behaviour of the sensor**

Application of α and β correcting parameters associated to the TECHNICAL TYPE of the low-cost sensor

Example of **technical type** correcting parameters derived for **SDS011** measuring **$PM_{2.5}$**

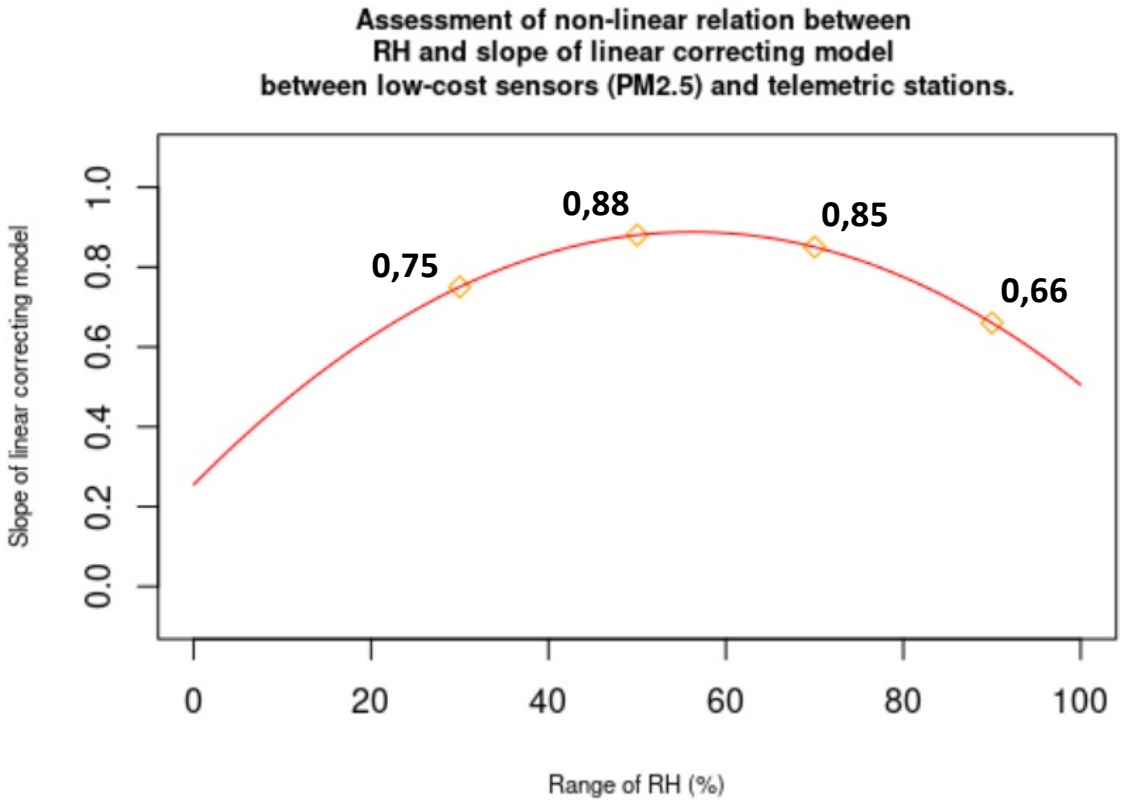
```
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 0 to 20 %"
"Qty IOTs: 0 --> mean slope: NaN~NA mean intercept: NaN~NA"
"Large time-window from 2021-05-06T12 to 2021-05-27T12 and RH ranging from 20 to 40 %"
"Qty IOTs: 4 --> mean slope: 0.75~0.19 mean intercept: 2.61~1.7"
"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"
```

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

Assessment of environmental conditions (i.e. relative humidity) impact on [PMx] measurements

Illustration with low-cost **SDS011** measurements of **$PM_{2.5}$** sampled during 6-27/05/2021

→ over 50% R.H., decreasing slope of correcting linear model tends indicating increasing overestimation from low-cost PMx measurements in high humidity conditions

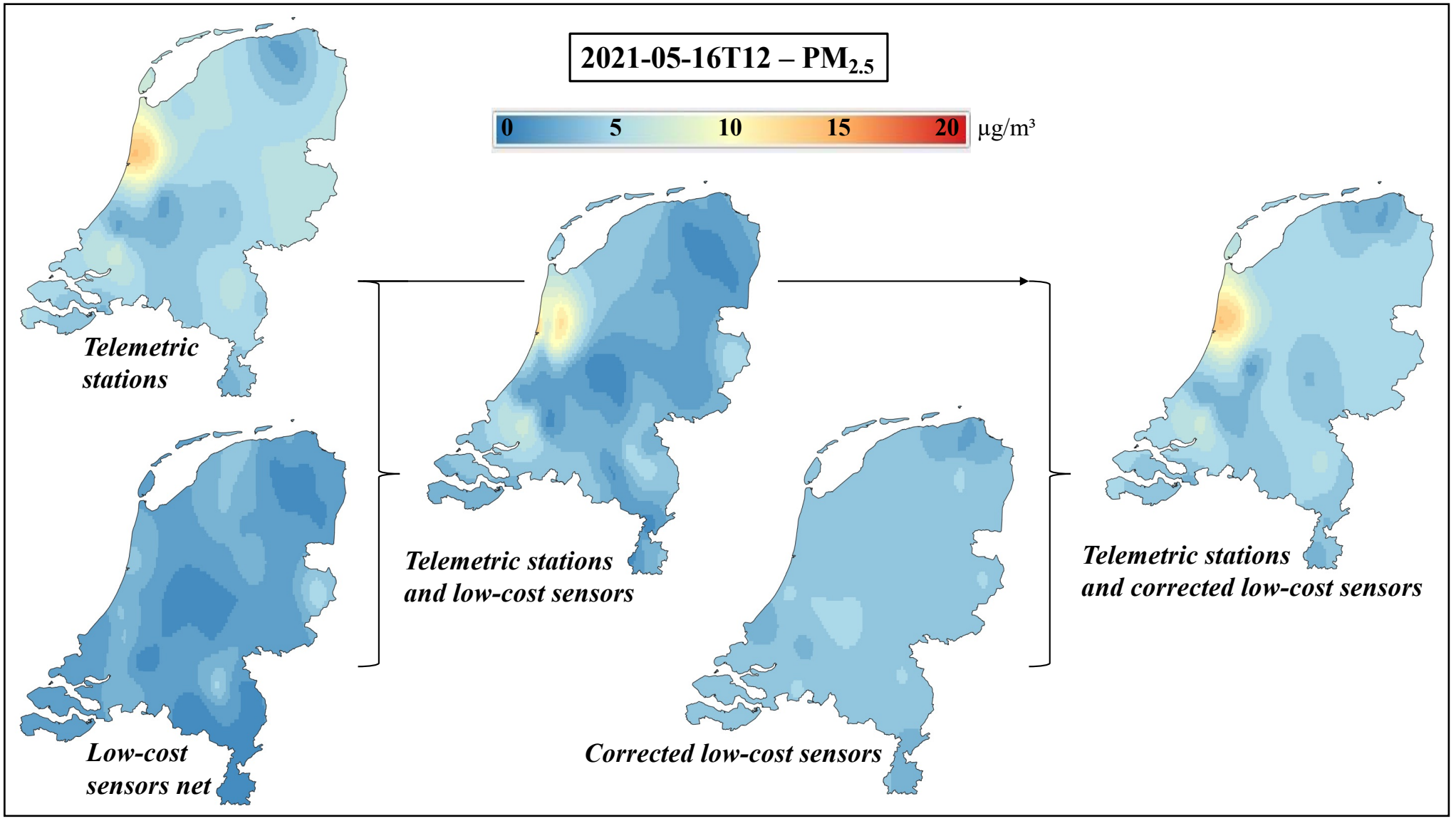


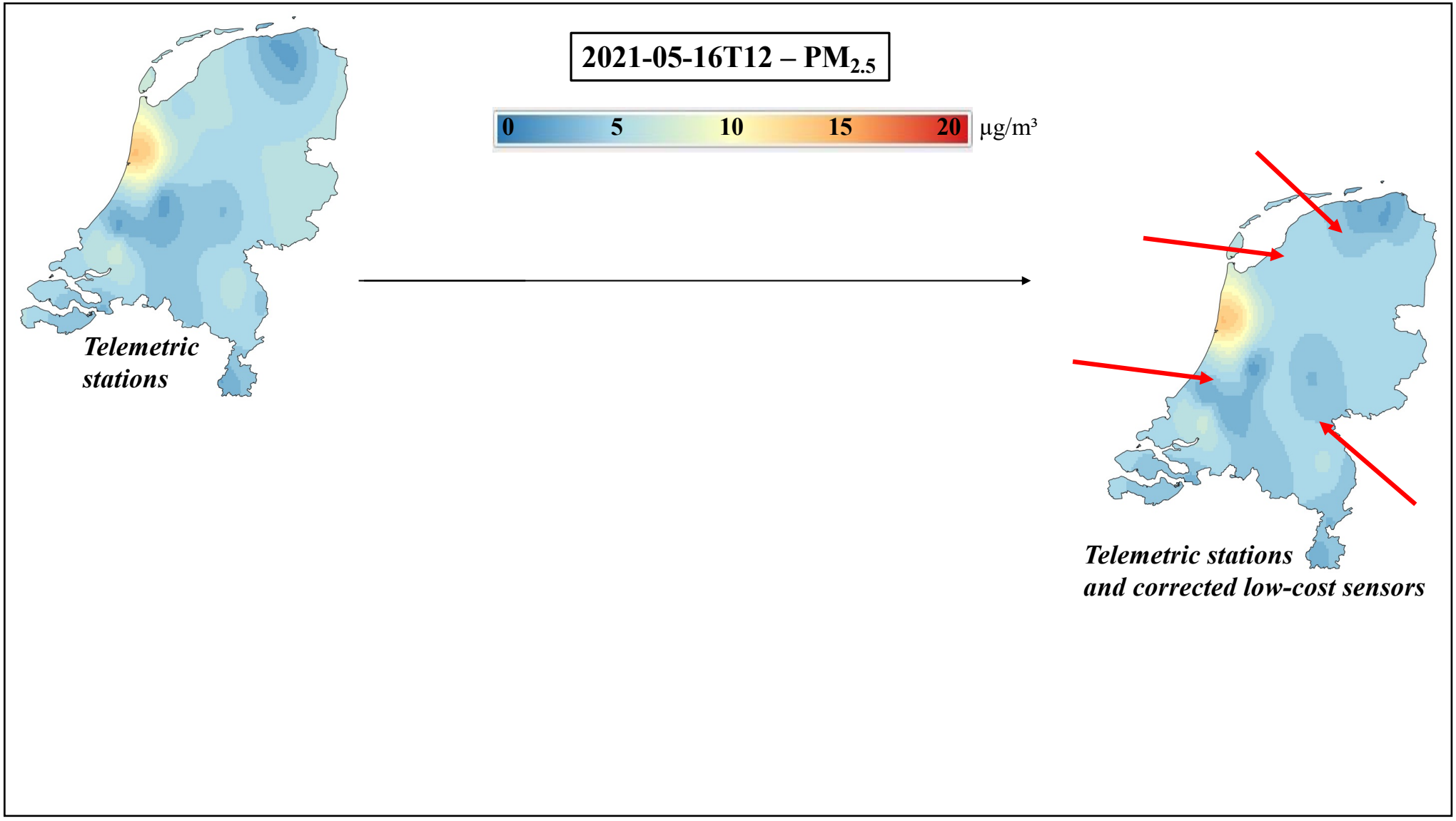
Assessment for linear correcting model of low-cost SDS011 sensors for $PM_{2.5}$ using a non-linear slope (m) determination based on relative humidity (RH).

$$[PM_{2.5}]_{corr} = \mathbf{m}.\ [PM_{2.5}]_{raw} + \mathbf{2,3}$$

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

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


2021-05-16T12 – PM2.5
0
5
10
15
20
µg/m³
Telemetric stations
Low-cost sensors net
Telemetric stations and low-cost sensors
Corrected low-cost sensors
Telemetric stations and corrected low-cost sensors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Thank you for your attention

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