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

Proposal for benchmarking

ISSeP – 07-09-2021

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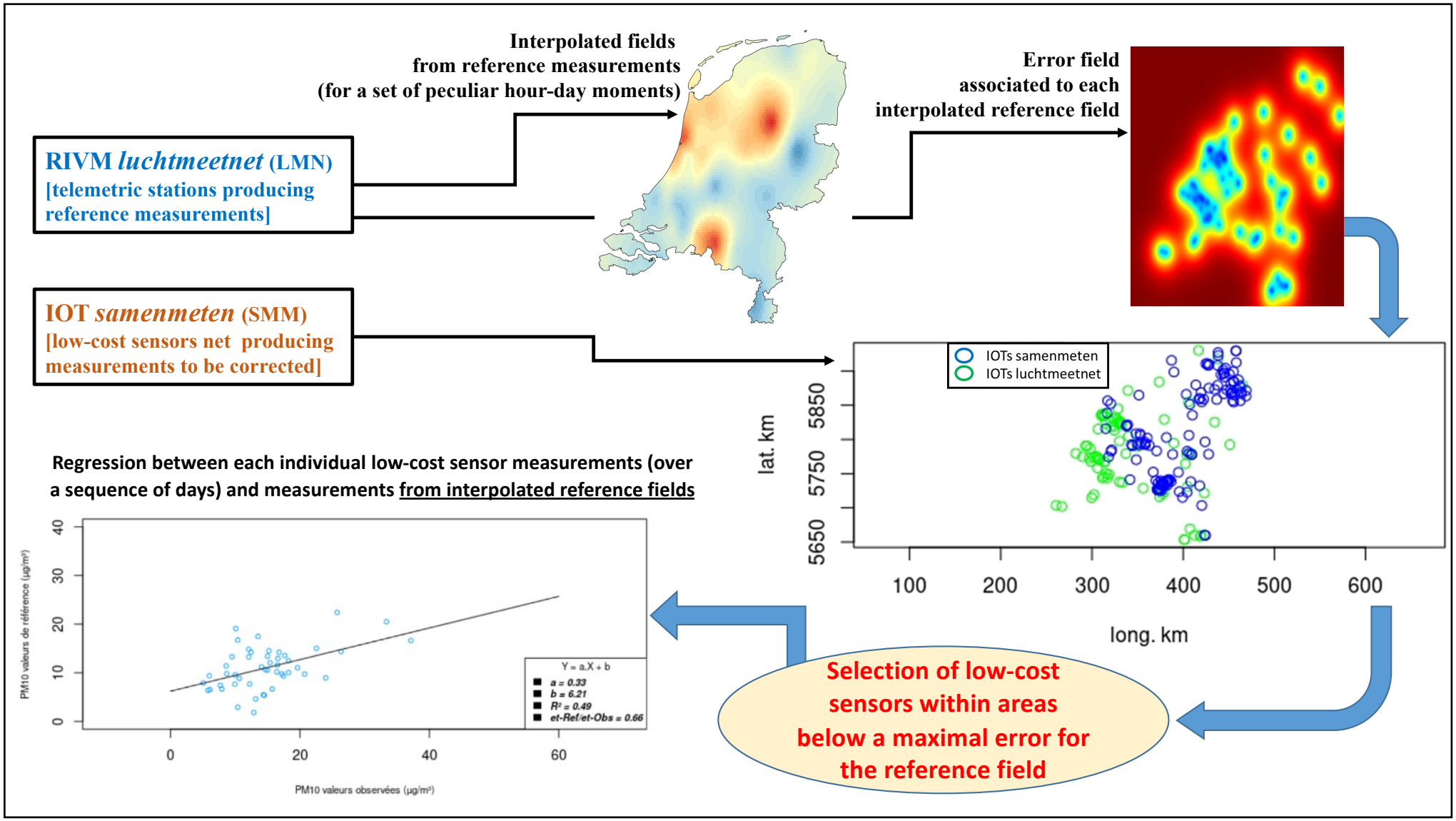
1. ISSeP strategy for benchmarking – short recall of formerly developed method
2. Improvement of method – iterative approach for low-cost sensors calibration
3. Results concerning the gain of individually calibrated low-cost sensors
4. Results concerning the production of PMx interpolated fields using an iterative calibrating strategy
5. Conclusions

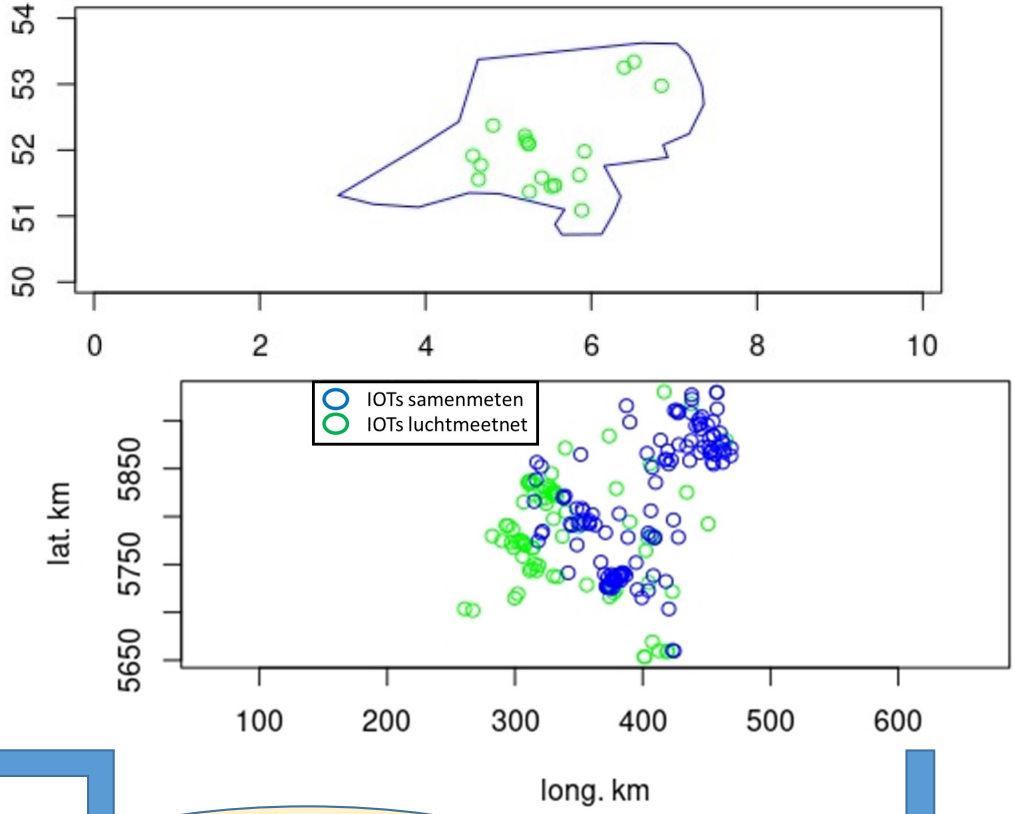
ISSeP benchmarking base strategy

- Use of a **spatial interpolating tool** to produce extended fields of reference values
- Association of an **error field** to the interpolated field of the PMx variable
- Selection of low-cost sensors regarding a **maximal acceptable error** of the interpolated reference field at each sensor location
- Selection of low-cost sensors regarding their **regression profiles** between proper measurements and reference values during a particular sampled time-window


Interpolated fields
from reference measurements
(for a set of peculiar hour-day moments)
Error field
associated to each
interpolated reference field
RIVM luchtmeetnet (LMN)
[telemetric stations producing
reference measurements]
IOT samenmeten (SMM)
[low-cost sensors net producing
measurements to be corrected]
IOTs samenmeten
IOTs luchtmeetnet
lat. km
5650
5750
5850
100
200
300
400
500
600
long. km
Regression between each individual low-cost sensor measurements (over
a sequence of days) and measurements from interpolated reference fields
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
Selection of low-cost
sensors within areas
below a maximal error for
the reference field

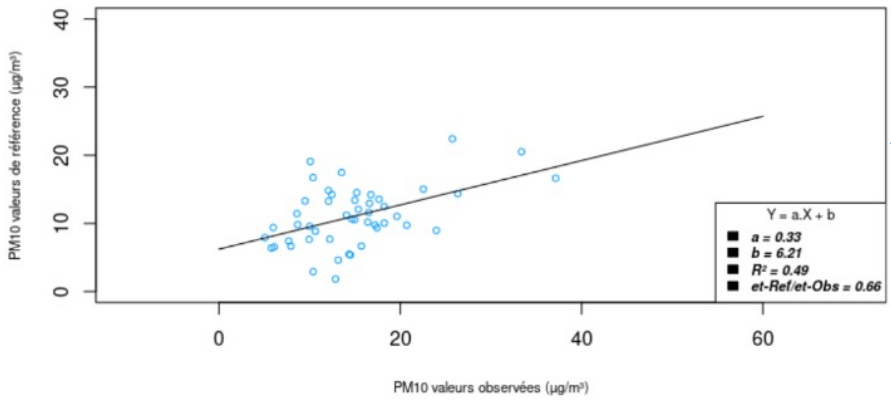
Selection of low-cost sensors regarding quality criteria for linear regression issues
(minimal and maximal slope)

Distribution of calibrated low-cost PM10 sensors, using a 1 iteration(s) process.



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

Regression between each individual low-cost sensor measurements (over a sequence of days) and measurements from interpolated reference fields



ISSeP benchmarking base strategy

Strong points

- The measurements given by low-cost sensors are compared to collocated values issued **from a concomitant field of spatially interpolated reference sources**, not to the mean of measurements from a set of closest telemetric stations.

- The difference between each low-cost sensor measurement and its corresponding value from the interpolated field is involved in the calibrating process **only if the interpolated field is trustable** i.e. if the error of the interpolation is acceptable at the considered location.

- Any selected low-cost sensor is corrected using a linear regression function whose **parameters are specific to the low-cost sensor as an individual IOT**.

- Robustness of the method is enhanced by making **regression parameters function of environmental variables** such as the relative humidity.

Weak points

- A quite **large amount of low-cost sensors are removed** from the initial pool of IOTs, mainly due to their locations in areas of the interpolated fields characterised by too high levels of spatial interpolation error.

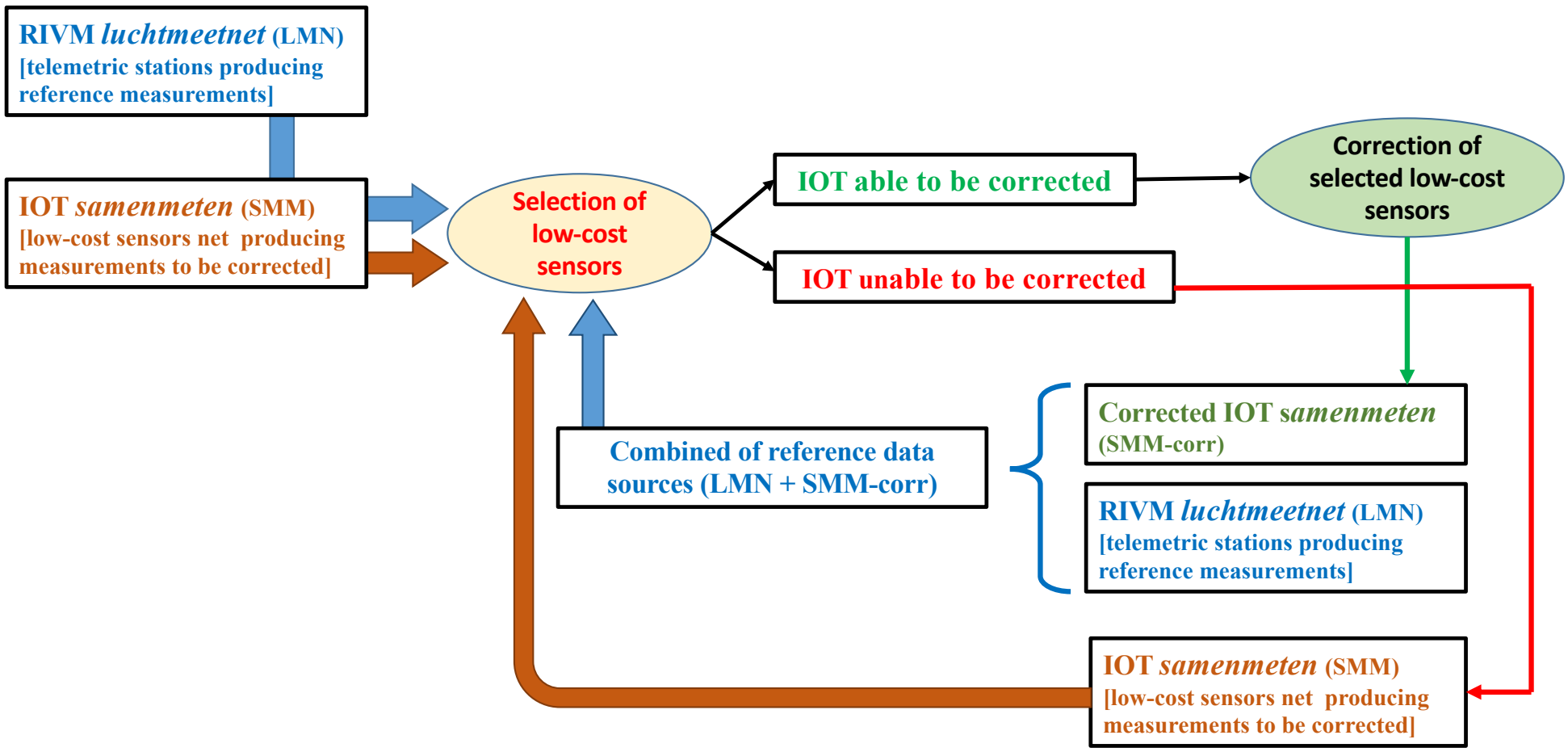
- Parameters ruling the interpolating process itself such as **correlation length and signal-to-noise ratio have to be set carefully** as they determine strongly the shape and the levels of the error field.

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** over which the error value of interpolations remains below the fixed limit
- **enlarge the pool of reference data points** from which are constructed the interpolated fieds
- **include the measurements procuded by calibrated low-cost sensors** to the pool of telemetric stations data
- **redo the inclusion** as far as new low-cost sensors are able to be calibrated with the same highest quality criteria

Iterative approach as a complement to base strategy



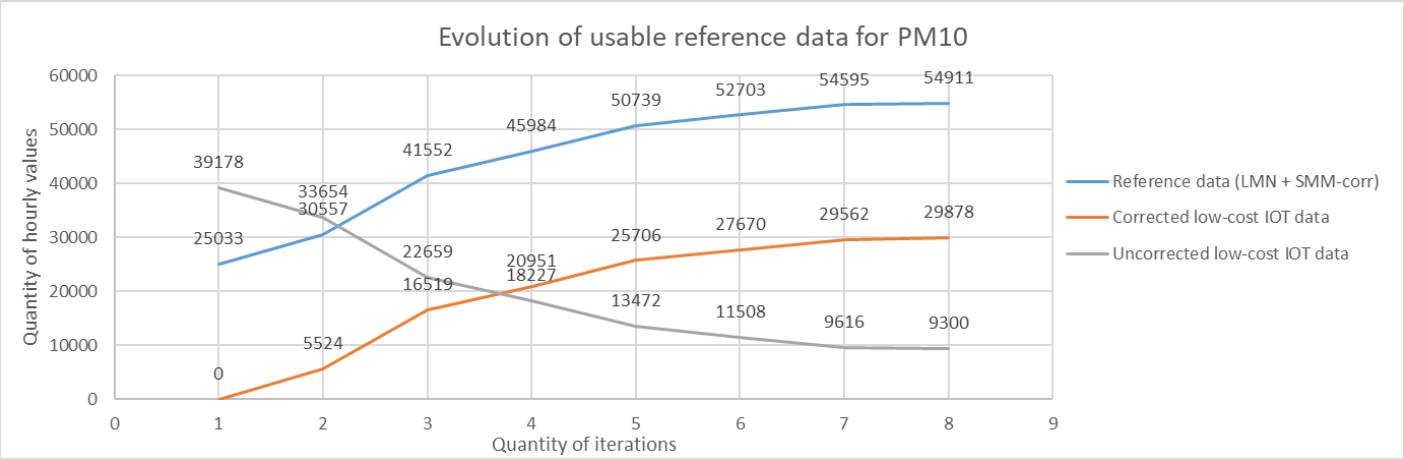
Iterative approach as a complement to base strategy

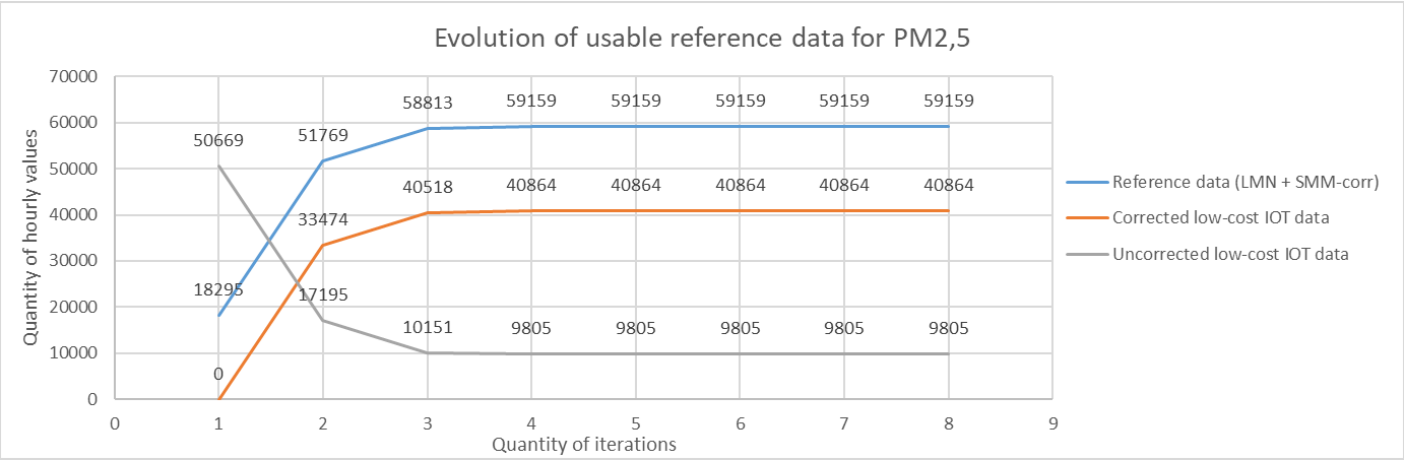
Benefits drained from an iterative calibrating approach :

- a **clear enhancement of the absolute amount** of individually calibrated low-cost sensors usable for the production of final [PMx] interpolated fields.

- a **moderate extension of the geographical areas** provided with calibrated low-cost sensors.

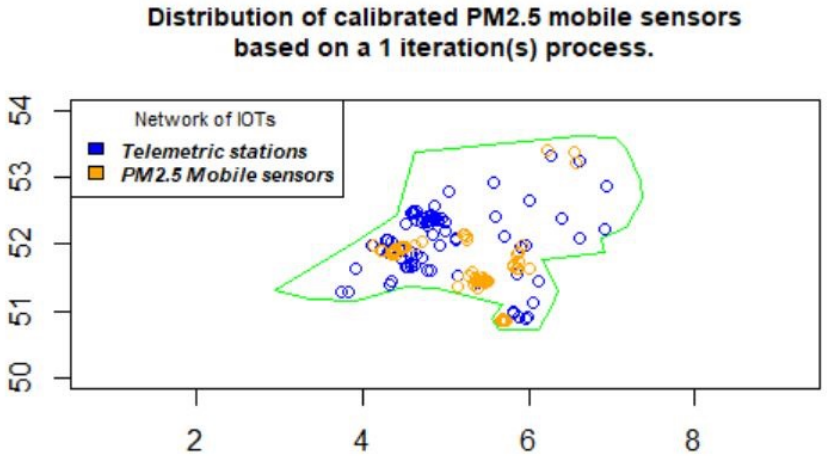
Iterative approach as a complement to base strategy

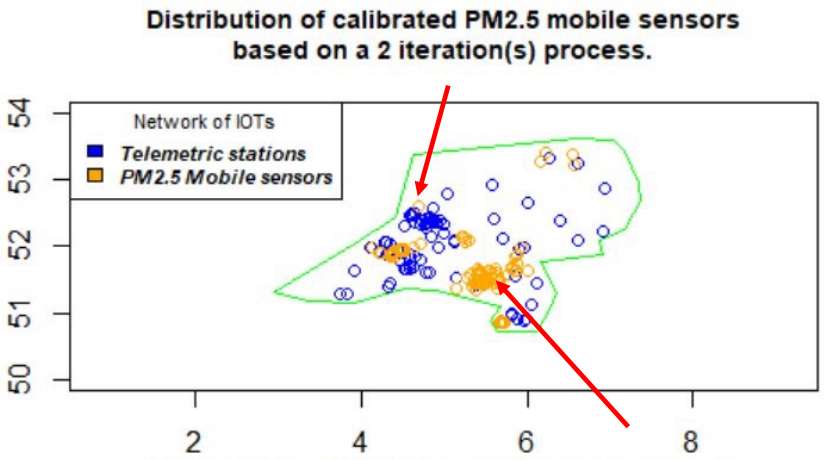




Results of a **8-iterations** calibrating process using hourly data, drained from 01/06/2021 to 15/06/2021 time-window.

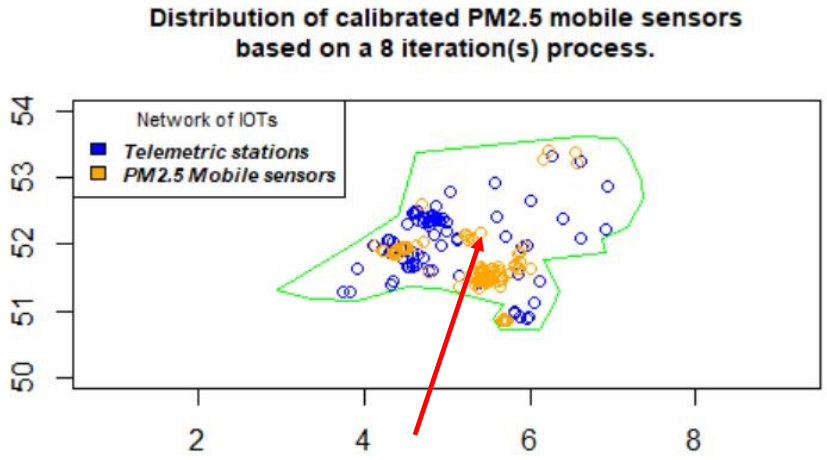
Iterative approach as a complement to base strategy





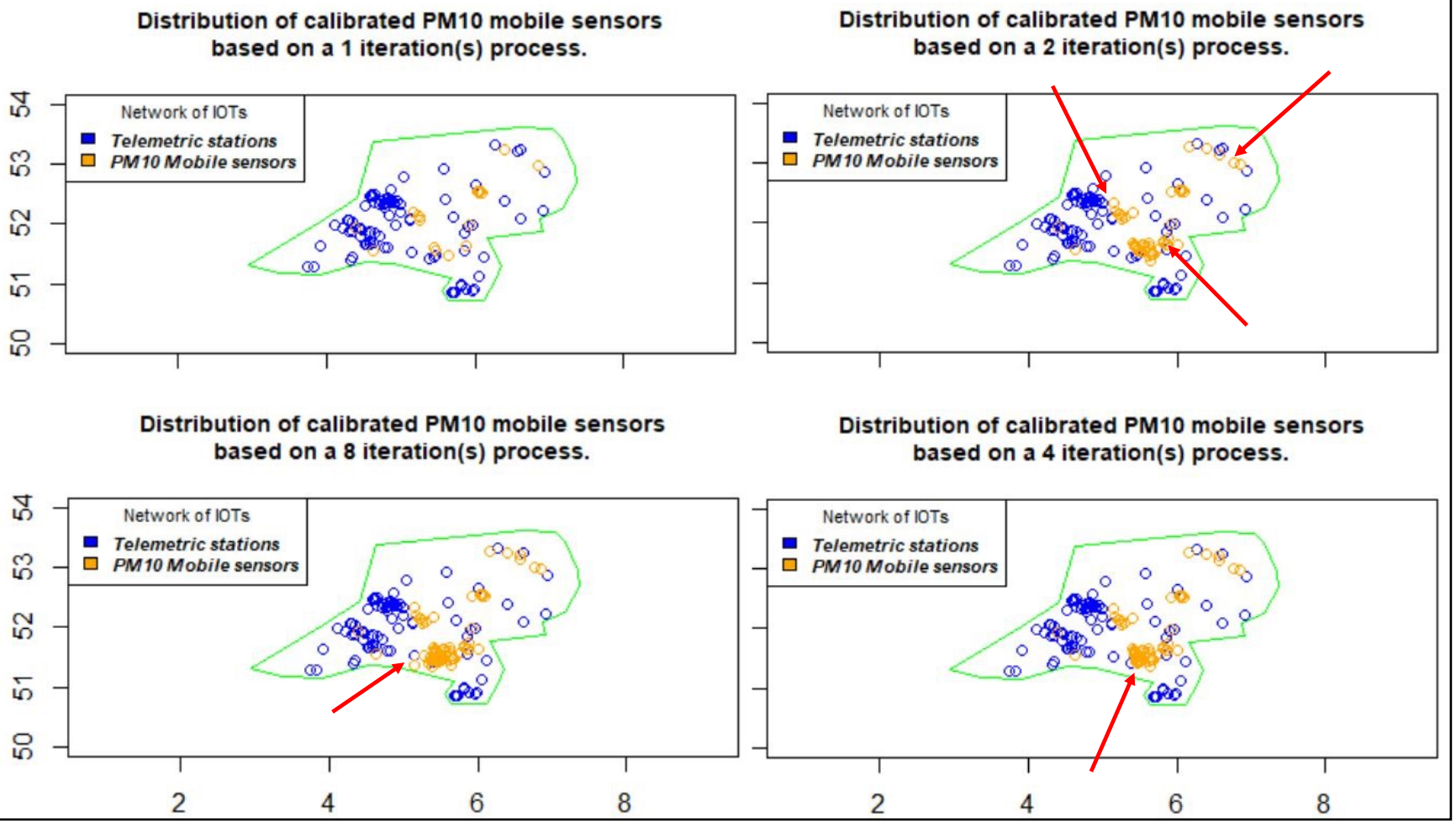
Evolution of **PM2.5** low-cost sensors coverture, with increasing iterations for calibrating process.

(hourly data, drained from 01/06/2021 to 15/06/2021)



Iterative approach as a complement to base strategy

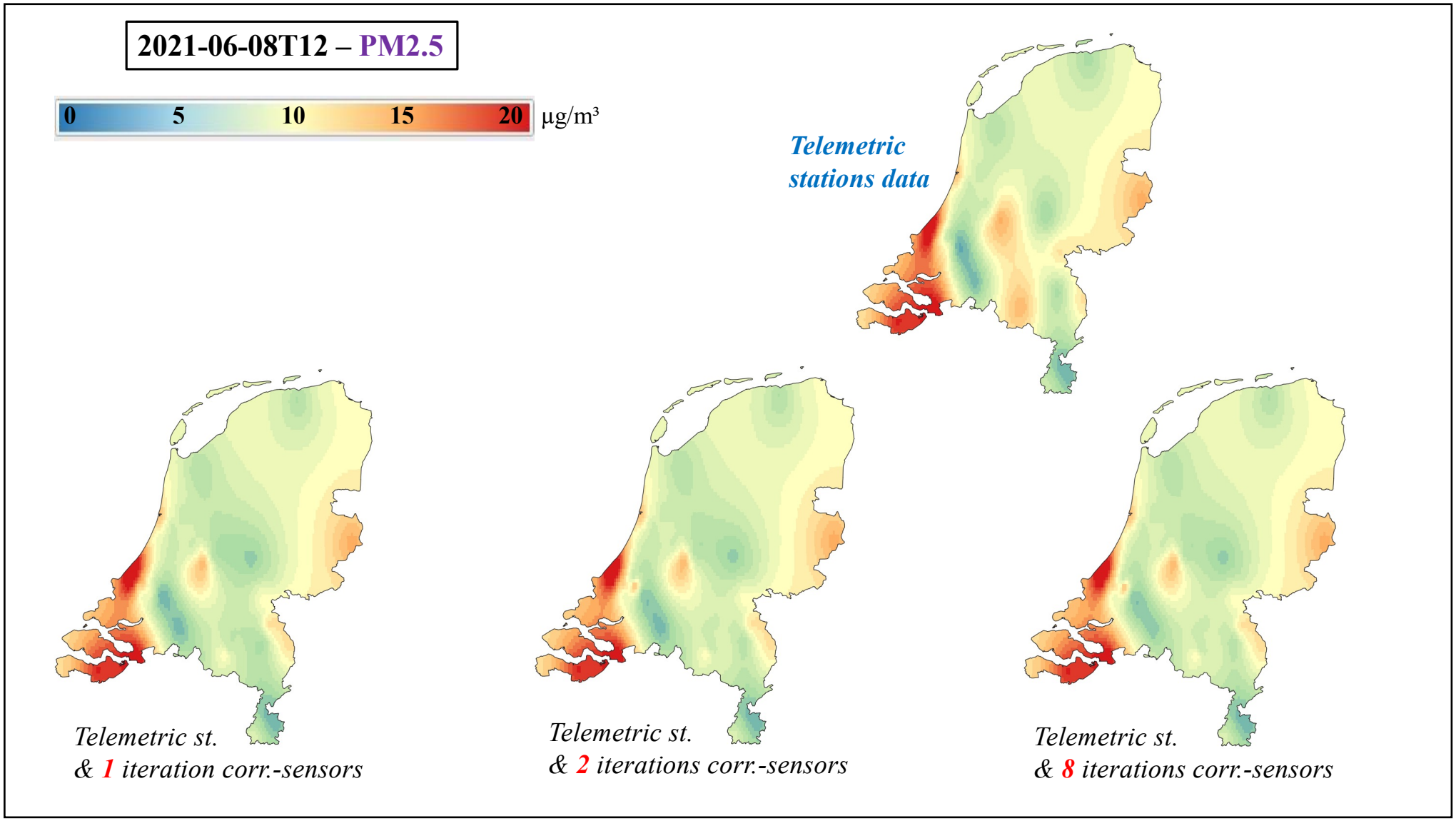
Evolution of **PM10** low-cost sensors coverture, with increasing iterations for calibrating process.

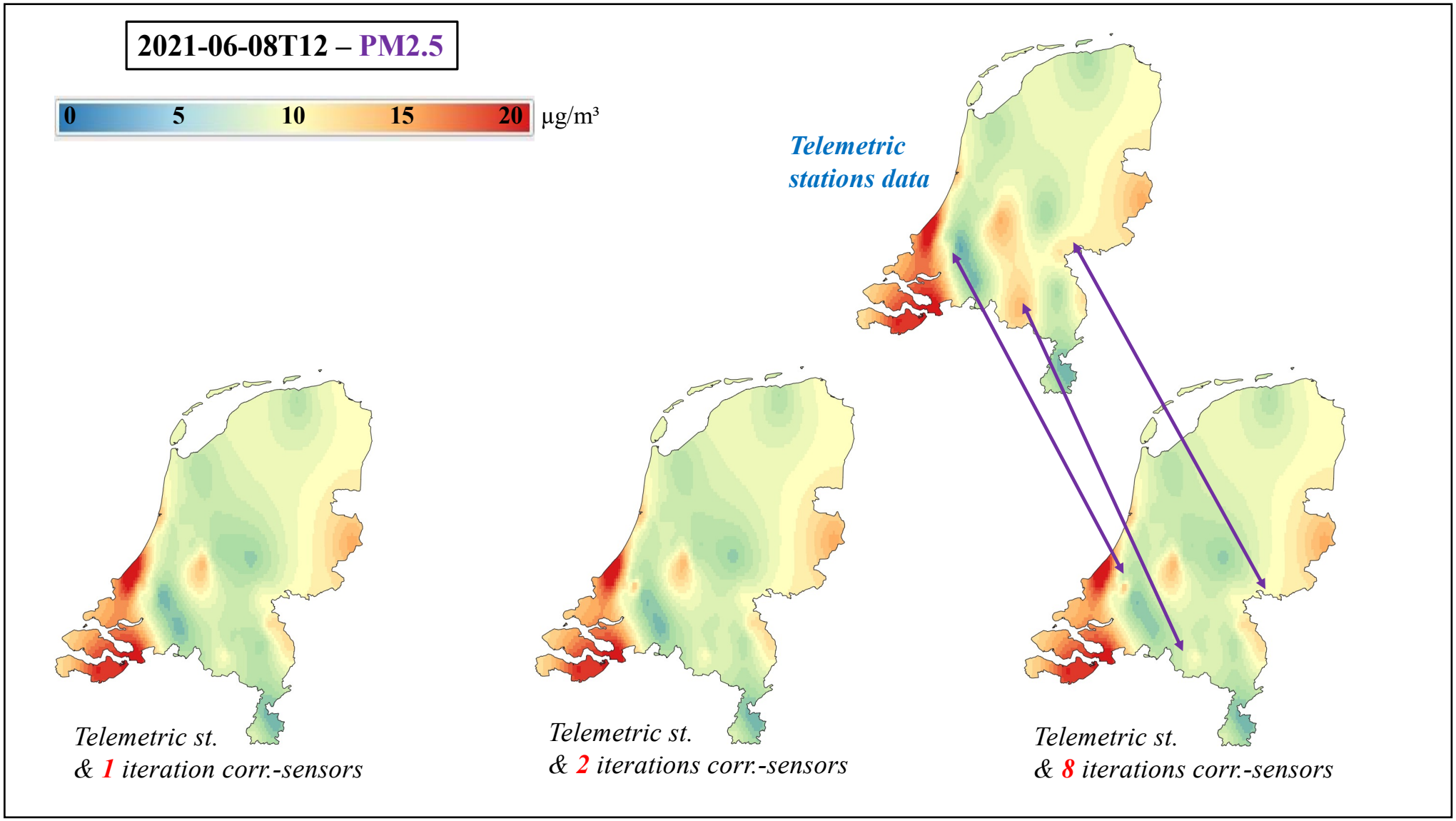


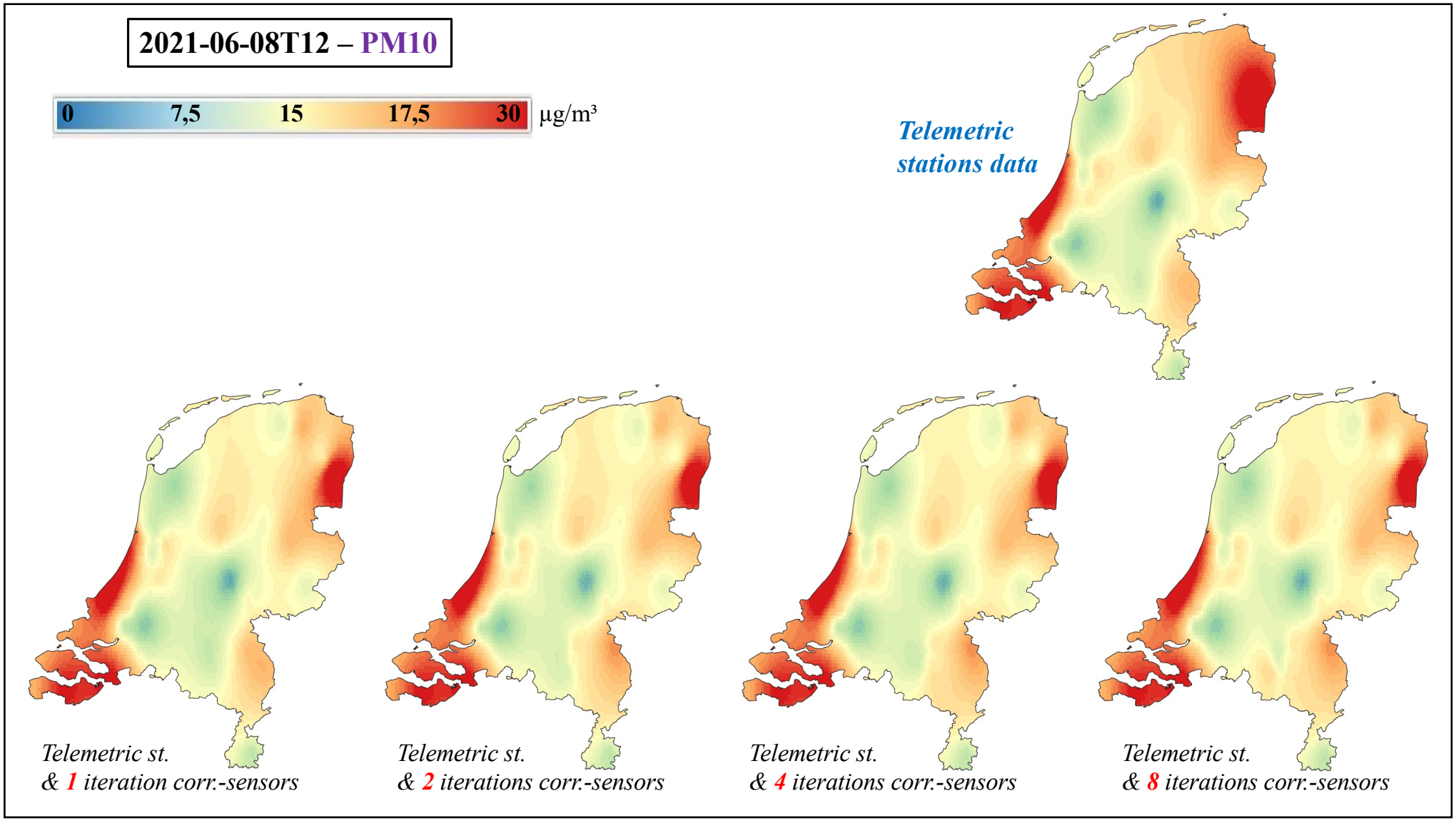
Results of [PMx] interpolated fields produced with combined telemetric and corrected low-cost sensors data

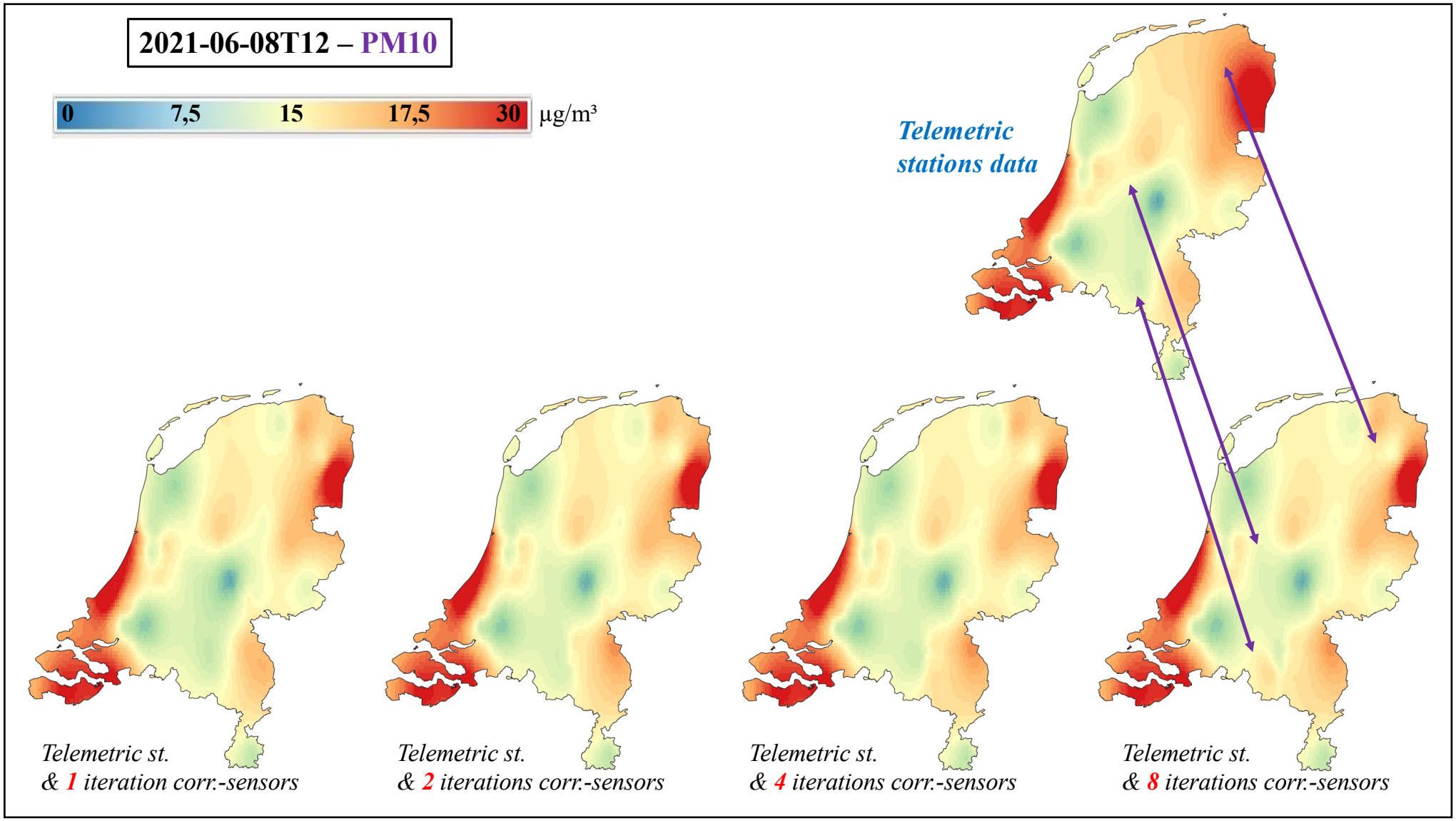
Comparison of increased iterations calibrating processes

- Following interpolated **[PMx] fields** are constructed with RIVM data from **08-06-2021 at 12h00**.
- Only data from low-cost sensors that are able to be individually corrected are involved in the data combination with telemetric stations data.
- For **PM10**, four combined sources fields are compared to an only telemetric source field. These four combined fields use an increasing pool of low-cost sensors, drained from calibrating processes based on 1 – 2 – 4 and 8 iterations.
- Similarly for **PM2.5**, however calibrated processes are only based on 1 – 2 and 8 iterations.


2021-06-08T12 – PM2.5
0
5
10
15
20
µg/m³
Telemetric stations data
Telemetric st. & 1 iteration corr.-sensors
Telemetric st. & 2 iterations corr.-sensors
Telemetric st. & 8 iterations corr.-sensors


2021-06-08T12 – PM2.5
0
5
10
15
20
µg/m³
Telemetric stations data
Telemetric st.
& 1 iteration corr.-sensors
Telemetric st.
& 2 iterations corr.-sensors
Telemetric st.
& 8 iterations corr.-sensors


2021-06-08T12 – PM10
0
7,5
15
17,5
30
µg/m³
Telemetric stations data
Telemetric st. & 1 iteration corr.-sensors
Telemetric st. & 2 iterations corr.-sensors
Telemetric st. & 4 iterations corr.-sensors
Telemetric st. & 8 iterations corr.-sensors


2021-06-08T12 – PM10
0
7,5
15
17,5
30
µg/m³
Telemetric stations data
Telemetric st. & 1 iteration corr.-sensors
Telemetric st. & 2 iterations corr.-sensors
Telemetric st. & 4 iterations corr.-sensors
Telemetric st. & 8 iterations corr.-sensors

Conclusions

- Individual calibration of low-cost sensors based on spatially interpolated references and an upper limit fixed for the interpolation error make **robust but highly selective** that calibrating strategy of sensors.

- An **iterative approach** for that individually calibrating strategy indeed **increases the pool of calibrated sensors**, being conserved highest quality criteria for calibration. However, the **extension of the calibrated low-cost sensors area remains limited**.

  Hypothesized reasons:

  - **scarcity of telemetric stations in various areas** impedes interpolated fields to reach required levels of quality
  - even in areas with satisfying interpolation, many low-cost sensors are avoided due to **unsatisfying regression profiles, probably due to inappropriate outdoor deployment** of the measuring device

- Sensors remaining out of an individual calibration strategy might be **corrected with parameters relevant for their technical types**. Furthermore, a **lower weight** should be observed in the interpolating process for sensors escaping from check based on a locally reconstructed and trustable reference.