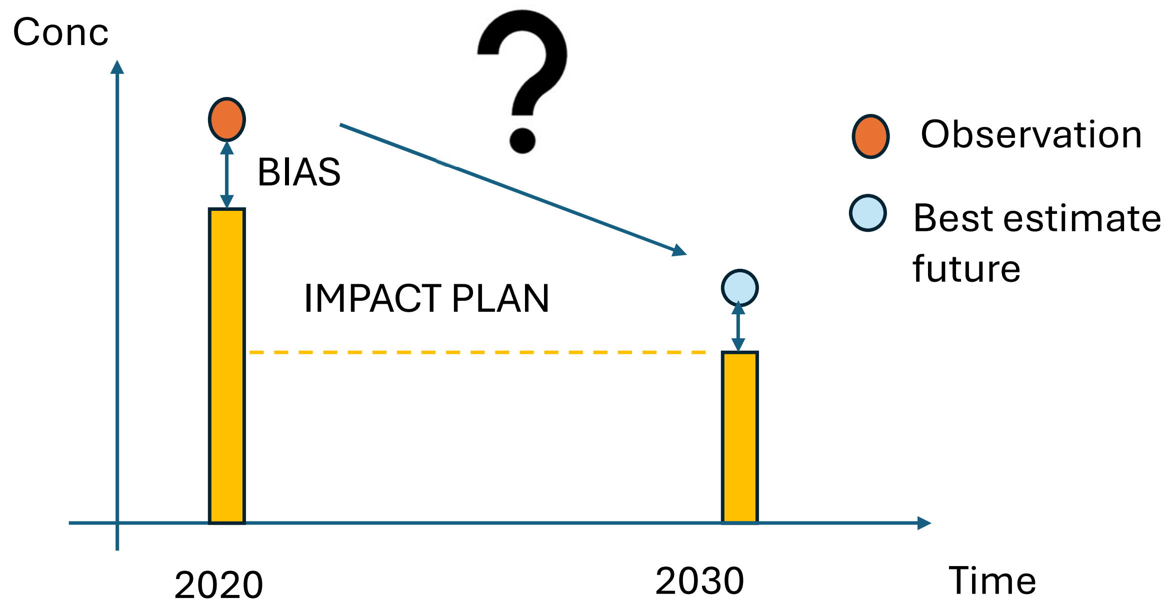
FAIRMODE WG5 model bias correction for planning: the first contribution of MASE Italian Air Quality Modelling Group

G. Bonafè[1], L. Colombo[2], C. Collaveri[3], F. Guarnieri[4],
S. Bande[5], R. Amorati[6], A. Dalla Fontana[7], A. Gaeta[8],
B. Intini[7], G. Leone[8], T. Magri[9], E. Malloci[10], M. A. Reatini[8],
L. Vitali[11], M. Mircea[11]
[1]ARPA FVG, [2]Arpa Lombardia, [3]ARPAT, [4]LaMMA, [5]Arpa Piemonte, [6]Arpae,
[7]ARPAV, [8]ISPRA, [9]Arpa VdA, [10]APPA Trento, [11]ENEA
Subset of the Working Group for AQM Application
Established by the Italian Ministry of Environment

XII Giornata della modellistica in ARIA(NET)

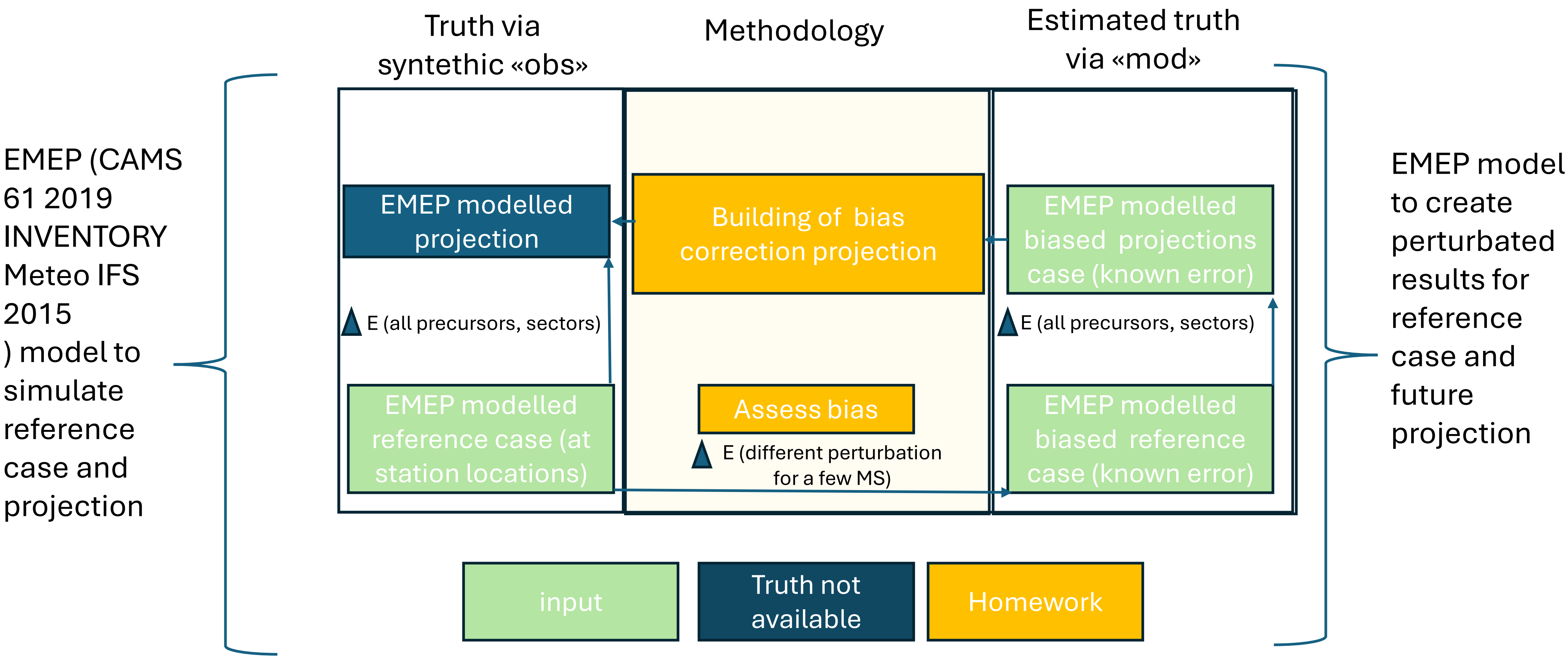
WG5 EXERCISE: WHAT IS THE PROBLEM



The new AAQD requests for an assessment of absolute concentration levels that can be benchmarked with limit or target values

- ✓ we have to eliminate the bias
- ✓ estimation at station: how to remove over the entire modelling domain?
- ✓ How to project bias into the future?

WG5 EXERCISE: BENCHMARKING STUDY



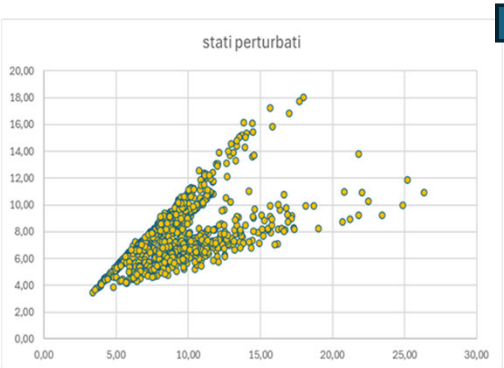
EMISSION REDUCTIONS

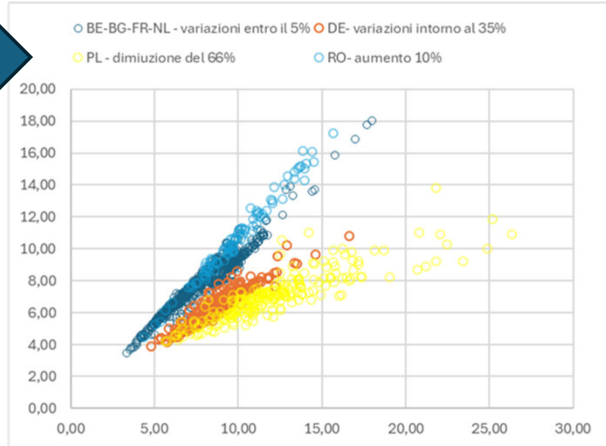
ΔE (all precursors, sectors): 50% for all Member States, precursors, sectors.

- Non-anthropogenic emission are kept constant!

ΔE (all precursors, sectors): X% per selected Member State / precursor.

- X is a known number at the JRC





scatterplots	m	q
Belgio	1,00	-1,00
Bulgaria	0,99	0,11
Francia	0,96	0,52
Germania	0,66	0,51
Netherlands	1,05	-1,23
Poland	0,36	2,67
Romania	1,13	0,53

METHODOLOGY APPROACHES

Homework

An unbiasing method can be described by defining:

- calibration method (C), based on input
- correction application (A) Assess bias
- spatialization algorithm (S), and
- the order of their application, the unbiasing sequence.

These elements provide a systematic approach to deriving and applying corrections to air quality scenarios by comparing a simulated base case with observed data, identifying biases, and using this information to remove them in the scenario.

Homework

Unbiasing Sequences

Each sequence of the following defines a unique order for calibration, correction, and spatialization processes, determining the workflow.

SCA (Spatialize - Calibrate - Apply): Spatializes the observed data to the entire grid, then calibrates and applies the correction algorithm.

CSA (Calibrate - Spatialize - Apply): First calibrates the correction coefficients, then spatializes them across the grid, and finally applies corrections.

CAS (Calibrate - Apply - Spatialize): The correction algorithm is calibrated and applied to monitoring sites, and then sparse data are spatialized across the grid.

CA (Calibrate - Apply): A correction is applied after calibration, either globally over the entire grid or locally at monitoring sites.

Homework

Correction Algorithms

- Additive (**Add**): Adds a constant value to correct biases.
- Multiplicative (**Mult**): Multiplies by a factor to adjust values.
- Linear (**Lin**): Applies linear corrections across the range of values.
- Rescaled Additive (**Resc**): Adds corrections scaled by the ratio between base case and scenario.
- Quantile-based (**Quant**): Corrects values based on quantile-specific factors.

Homework

Calibration Methods

- Point-based (**All**): A single set of coefficients is calibrated globally, using data from all monitoring sites combined.
- Point-based (**Each**): A distinct set of coefficients is calibrated locally for each monitoring site.
- Grid-based (**Grid**): Calibration of the coefficients applied over the entire grid to correct for bias.
- Cell vs Cell (**Cell**): Calibration considers each cell individually, adjusting coefficients to remove bias at the cell level.
- Cell Neighborhood (**Neigh**): Calibration uses information from surrounding cells to adjust coefficients for bias removal.

Homework

Spatialization Algorithms

- Thin Plate Spline (**tps**)
- Distance Weighted (**idw**)
- Ordinary Kriging (**ok**)
- Kriging with External Drift (**ked**)
- Multiple Linear Regression + Residual Interpolation (**mlr**)
- Successive Correction Method (**scm**)

Spatialization algorithms determine how information is propagated from points to the grid. Depending on the sequence of unbiasing, the propagated information can either be air quality indicators (for sequences SCA, CAS) or the coefficients of correction algorithms (for sequence CSA).

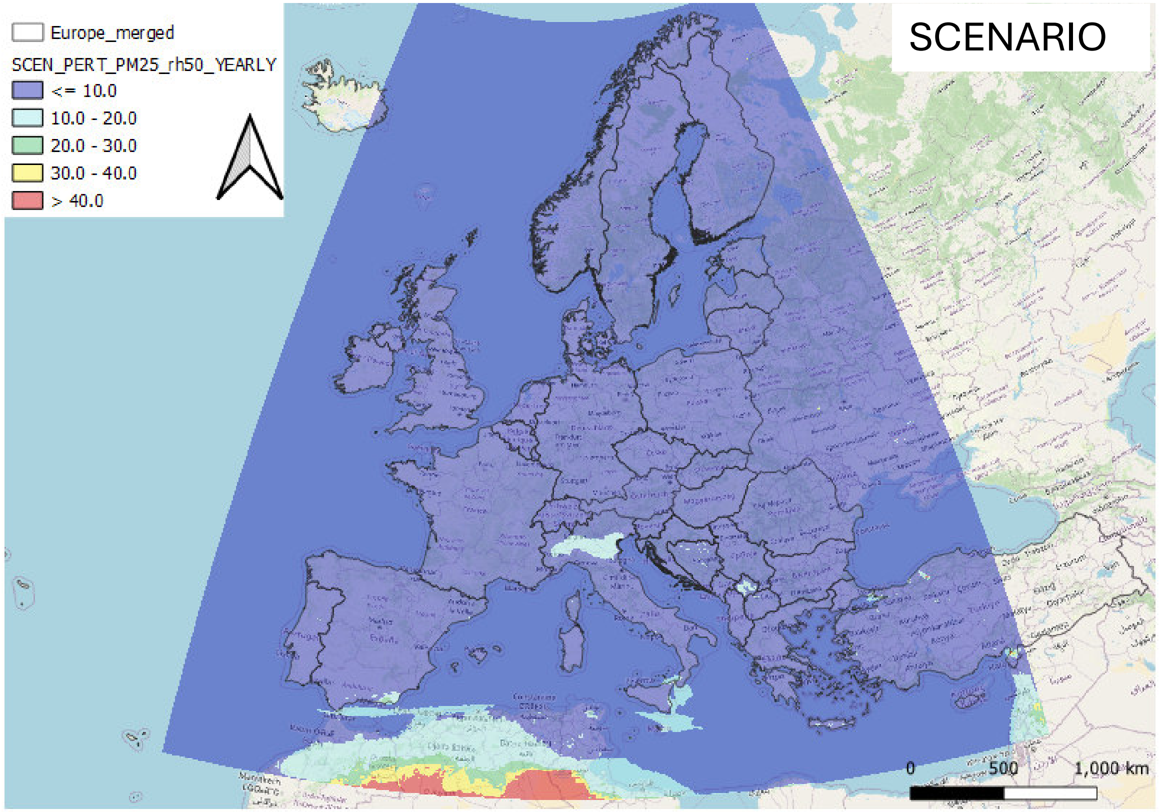
Sequence	Calibration	Correction Algorithm	#
SCA	Grid	Add, Mult, Lin, Resc, Quant	5
	Cell	Add, Mult, Resc	3
	Neigh	Add, Mult, Lin, Resc	4
CSA, CAS, CA	Each	Add, Mult, Resc	9
CAS, CA	All	Add, Mult, Lin, Resc, Quant	6

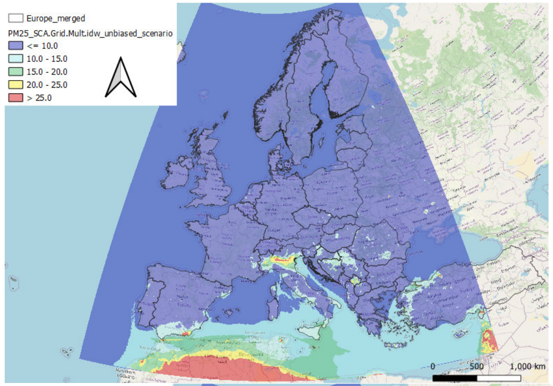
This table summarizes for four unbiasing sequences, 27 possible combinations of calibration methods and correction algorithms, six of which do not require spatialization. Each sequence that involves spatialization can be paired with one spatialization algorithms mentioned previously (ns = 6). Therefore, the potential maximum number of combinations is (nSCA + nCAS + nCSA) · ns + nCA = 168

A PRELIMINARY RESULT: YEARLY PM2.5

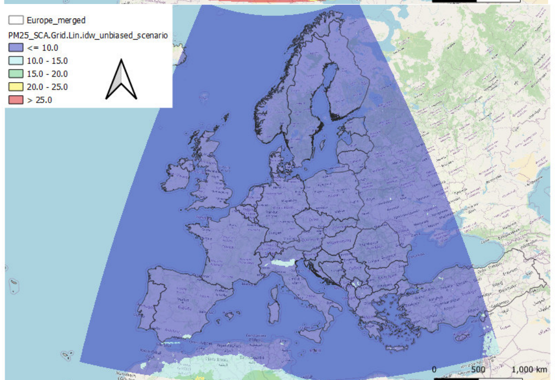
- ✓ **1 indicator: PM2.5 annual average**
- ✓ **1 unbiasing sequence: SCA (Spatialize-Calibrate-Apply)**
- ✓ **2 calibration methods:**
  - Grid (global)
  - Cell (local)
- ✓ **3 correction algorithms:**
  - Add (additive),
  - Mult (multiplicative)
  - Lin (linear)
- ✓ **4 spatialization methods:**
  - tps (thin plate spline)
  - idw (inverse distance weighted)
  - ok (ordinary Kriging)
  - ked (Kriging with external drift)

A PRELIMINARY RESULT: PM2.5 YEARLY FOCUS

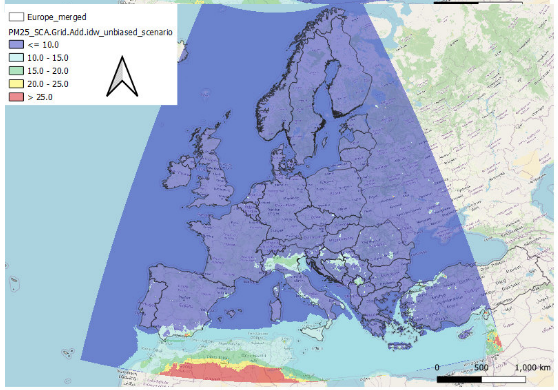




GRID.MULT
Multiplies by a factor to adjust values.



GRID.LIN
Applies linear corrections across the range of values.

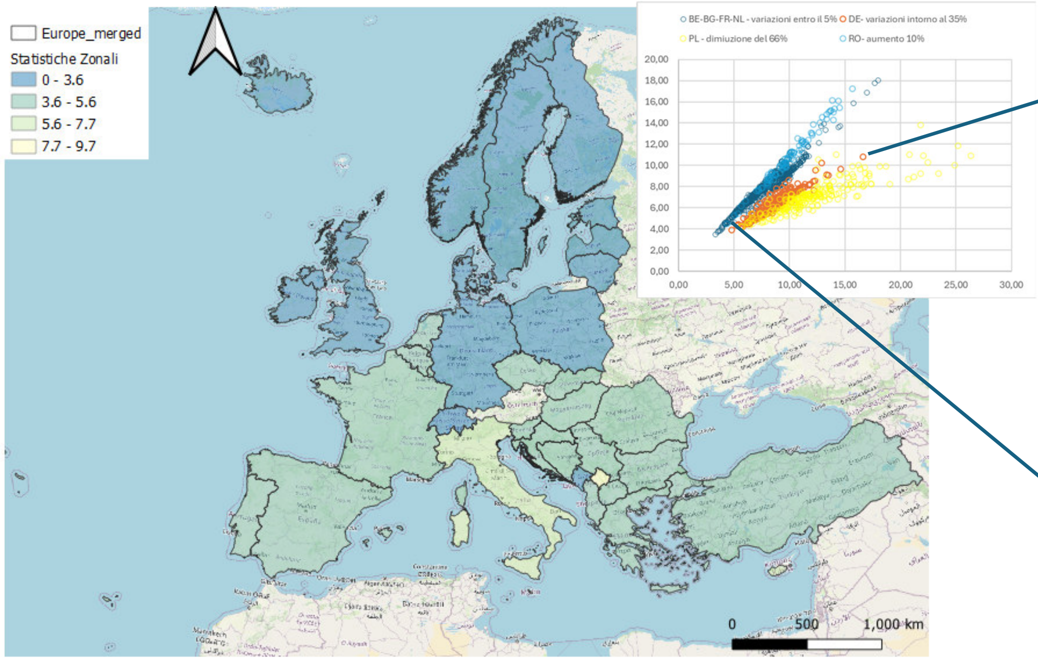


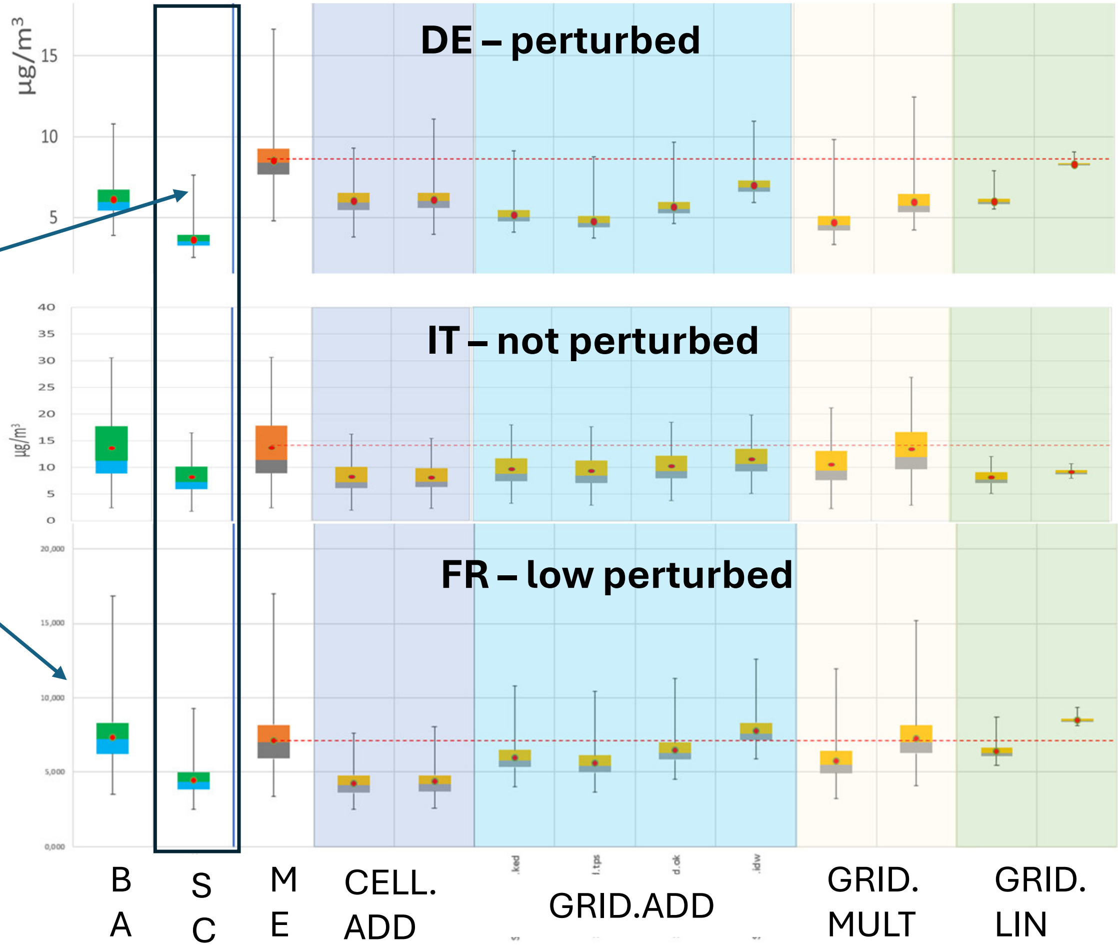
GRID.ADD
Adds a constant value to correct biases.

REMARKS:

- ✓ Correction spatialized all over the Europe
- ✓ We focus on only some results SCA (Spatialize - Calibrate - Apply): Spatializes the observed data to the entire grid, then calibrates and applies the correction algorithm.

SCENARIO





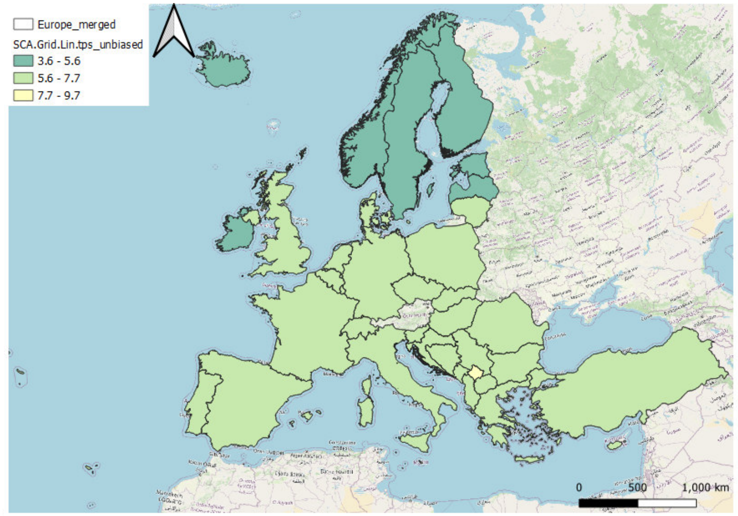
REMARKS:

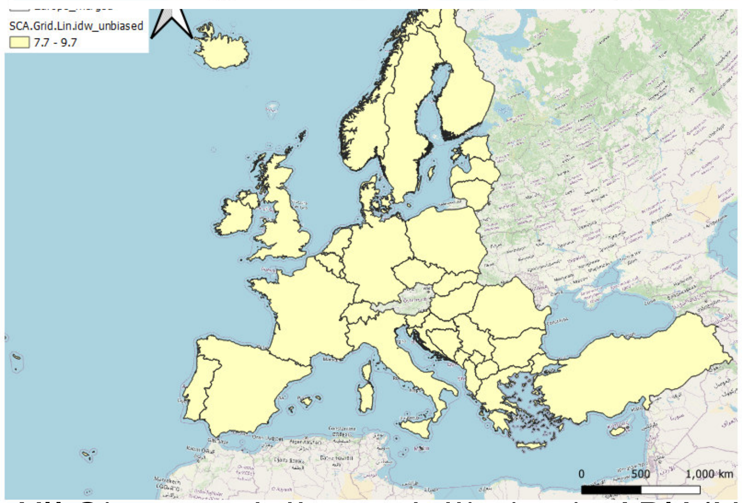
- ✓ Boxplot shows that basecase and measured are similar where no (or low) perturbation carried out
- ✓ Unbias is propagated all over EU after computation only in some States
- ✓ Results are affected by «starting point»

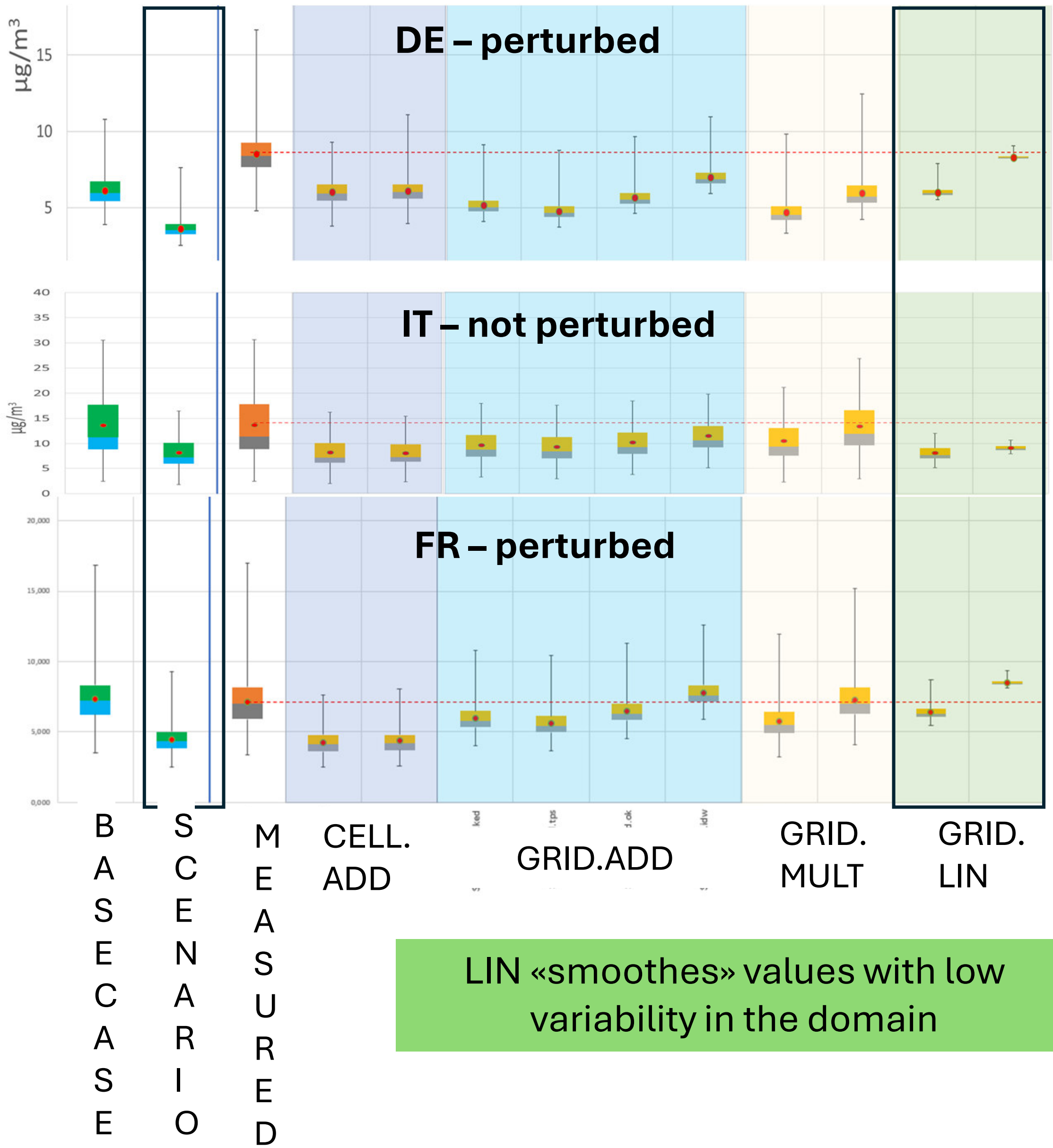
Perturbation are greater in some countries than in others

GRID.LIN

Applies linear corrections across the range of values.

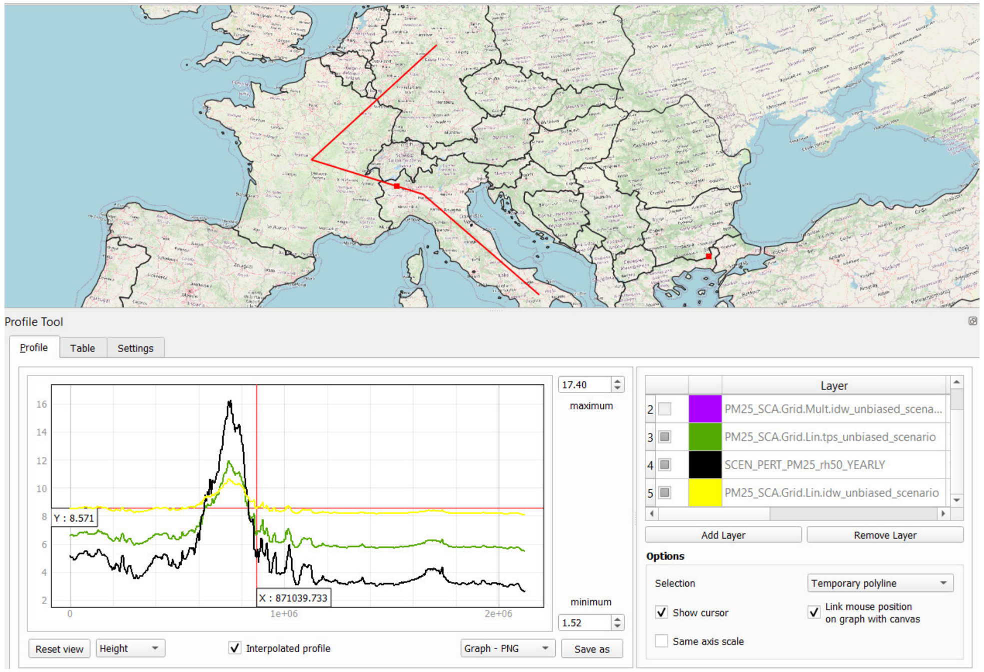


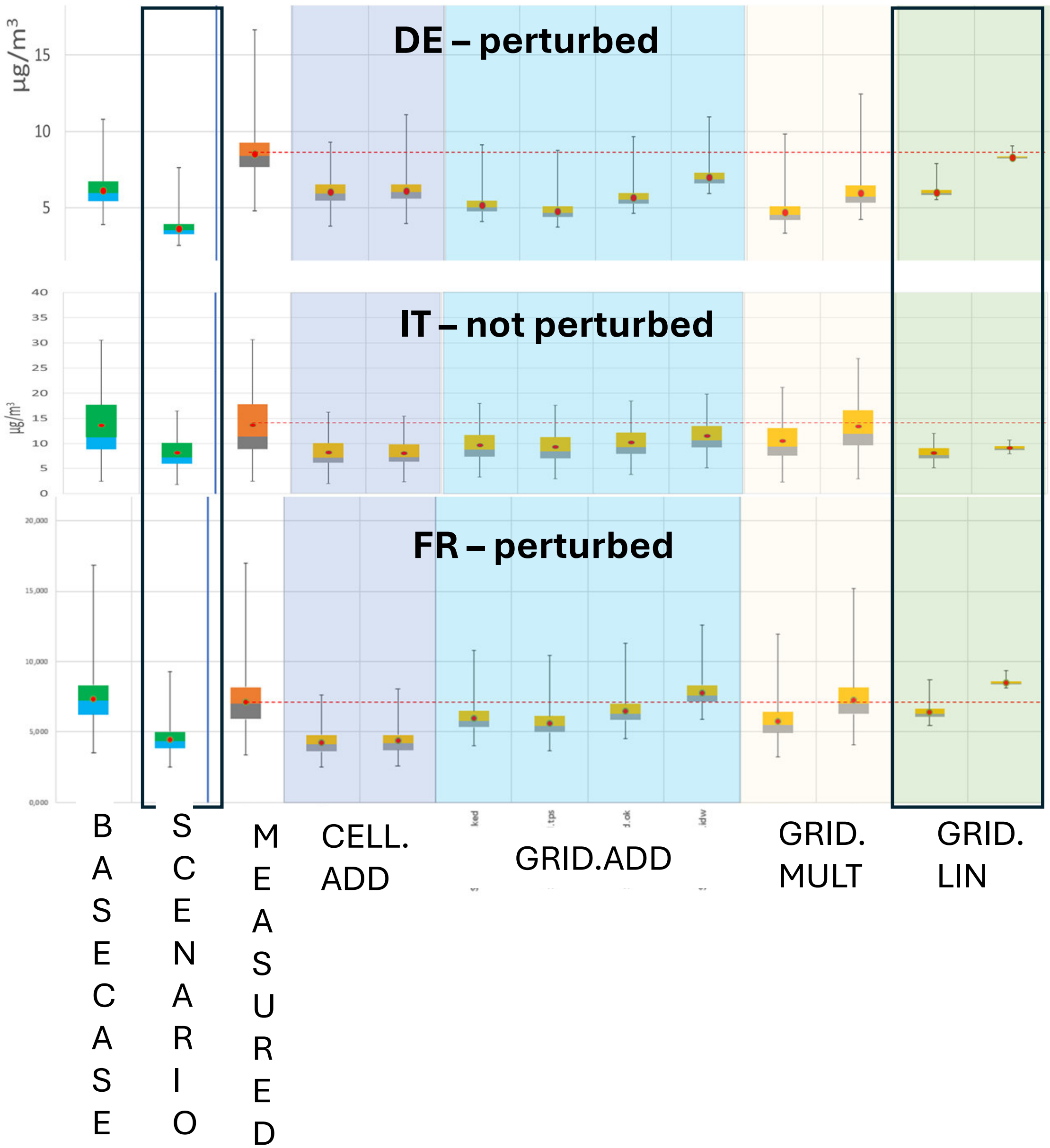




LIN «smoothes» values with low variability in the domain

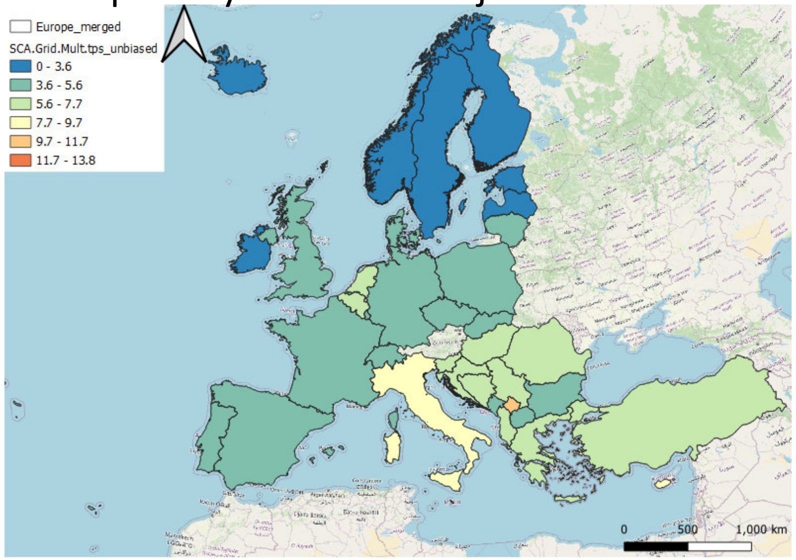
GRID.LIN
Applies linear corrections across the range of values.

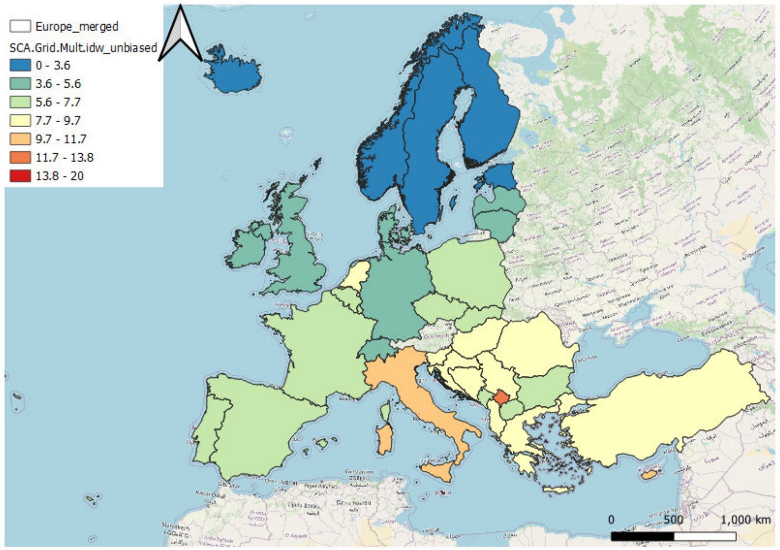




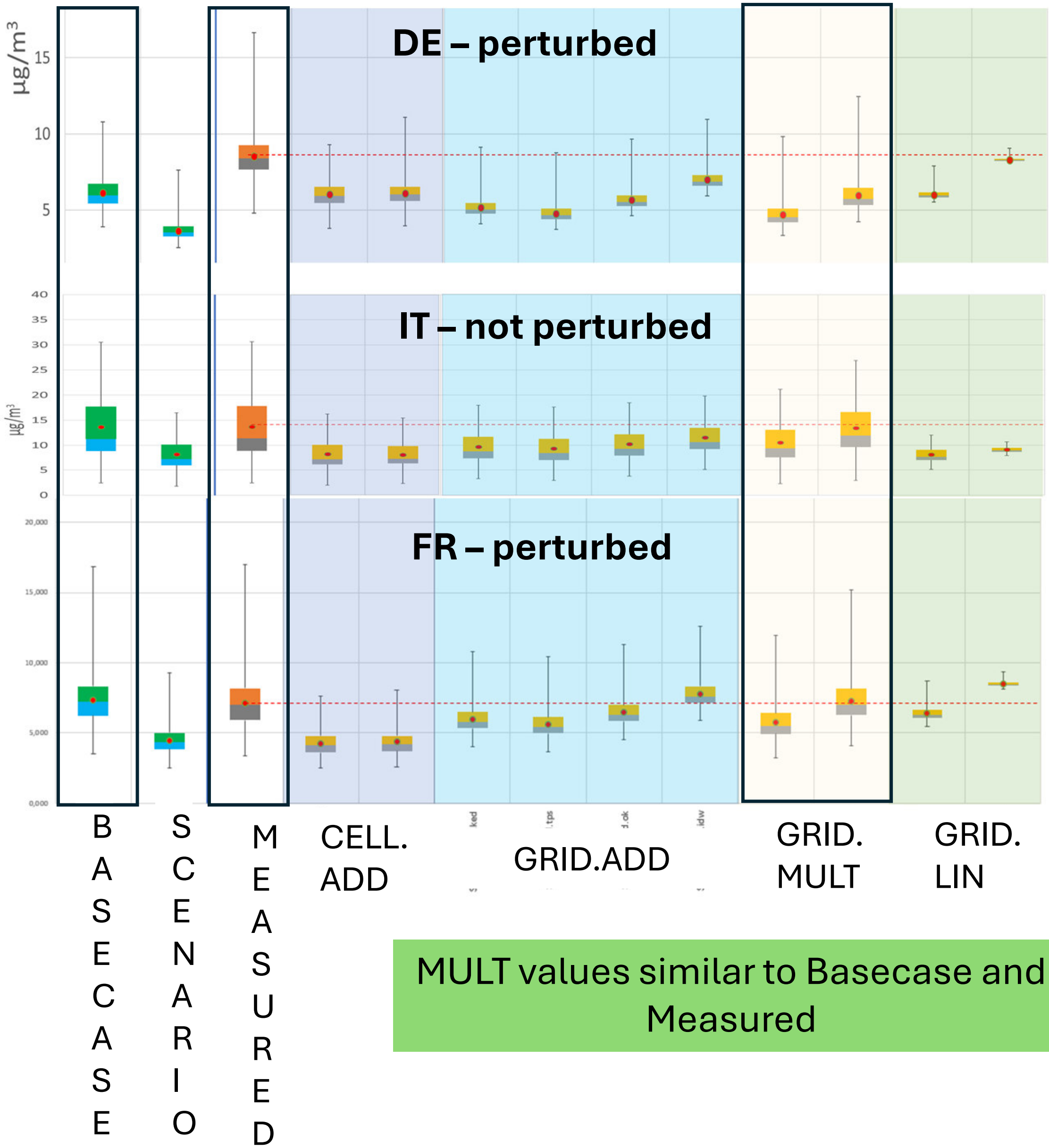
REMARKS:
- In general IDW is higher than TPS

GRID.MULT
Multiplies by a factor to adjust values.



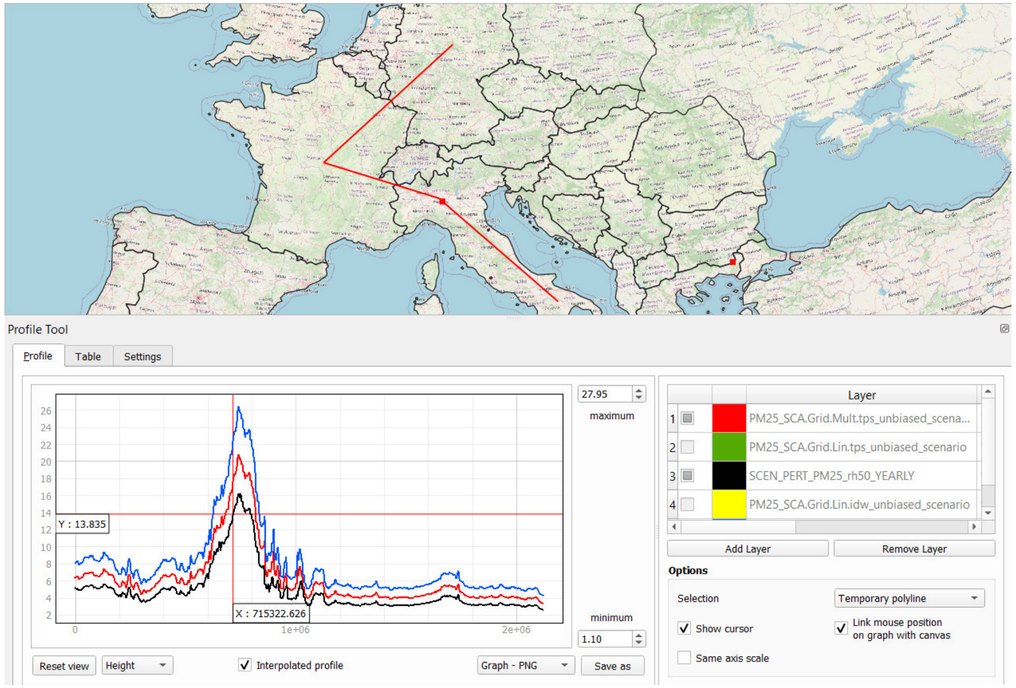


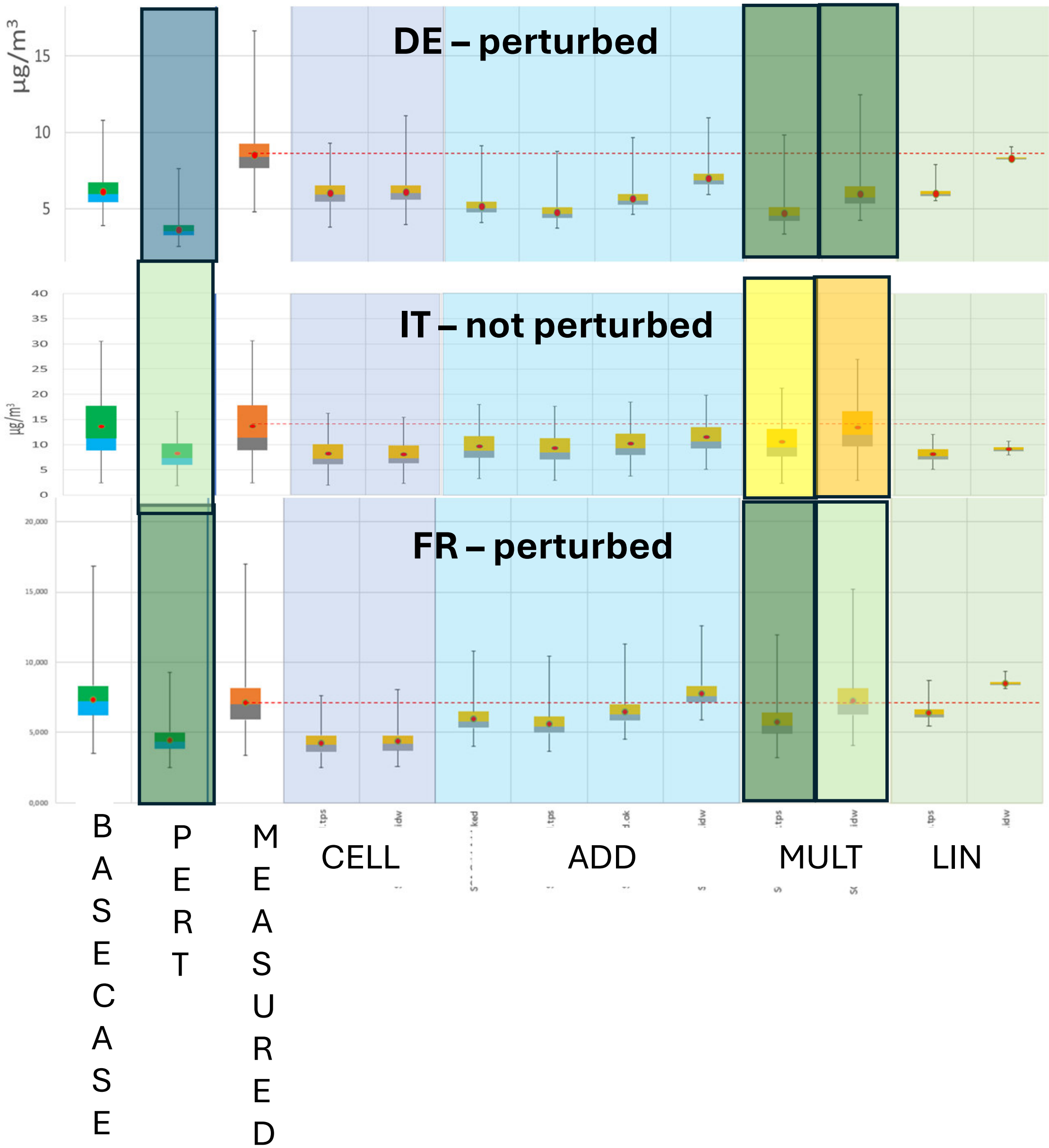
Genera



MULT values similar to Basecase and Measured

Grid.Mult.xxx



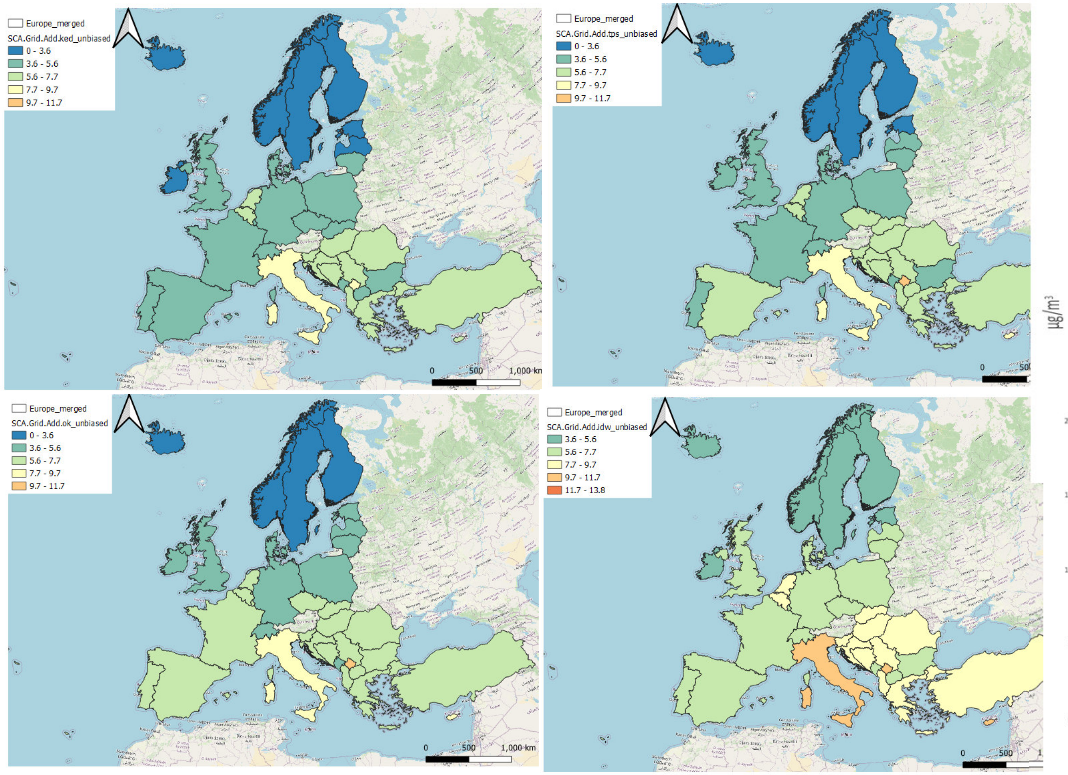


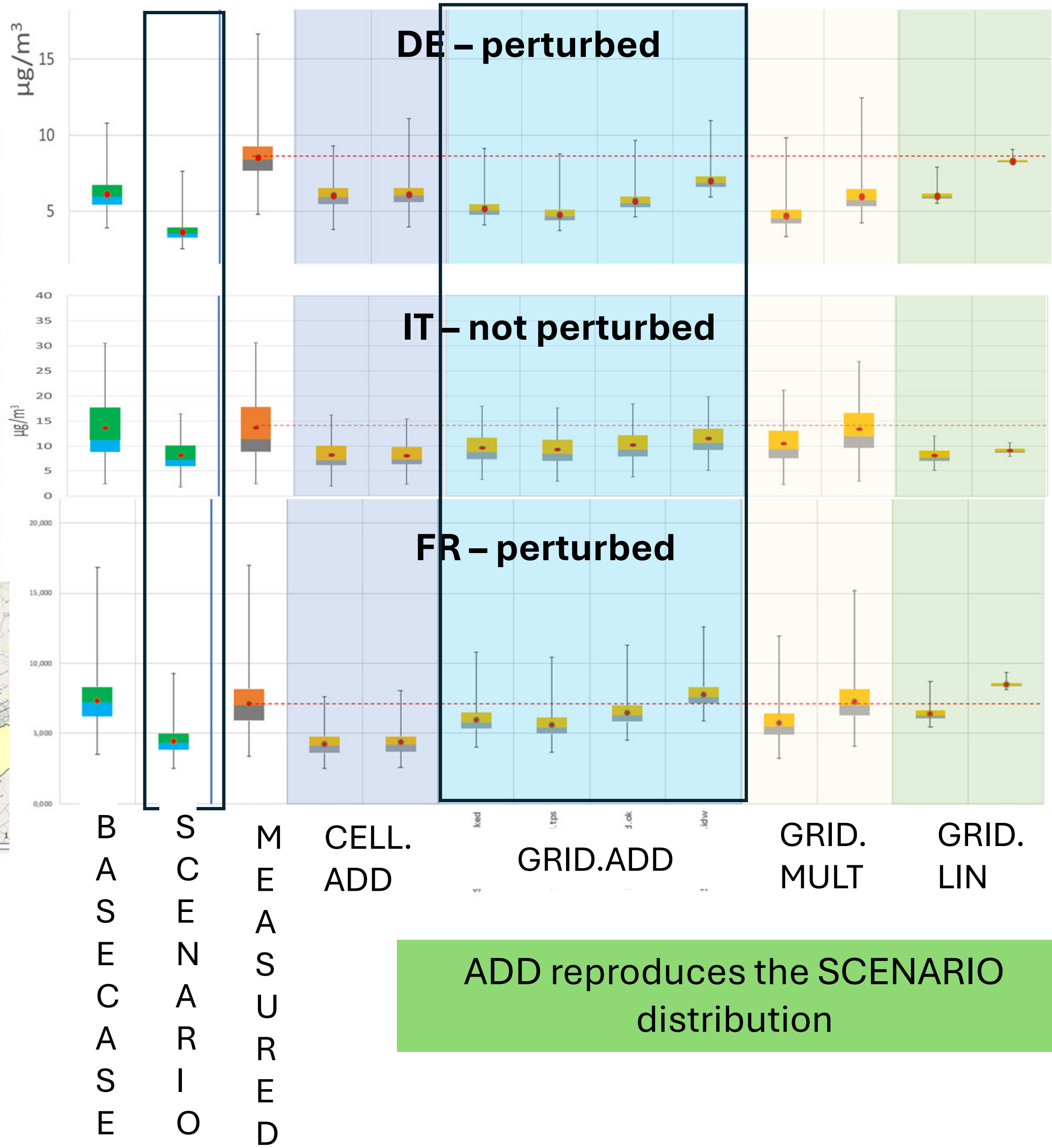
REMARKS:

- In general IDW is higher than TPS

GRID.ADD

Adds a constant value globally to correct biases.

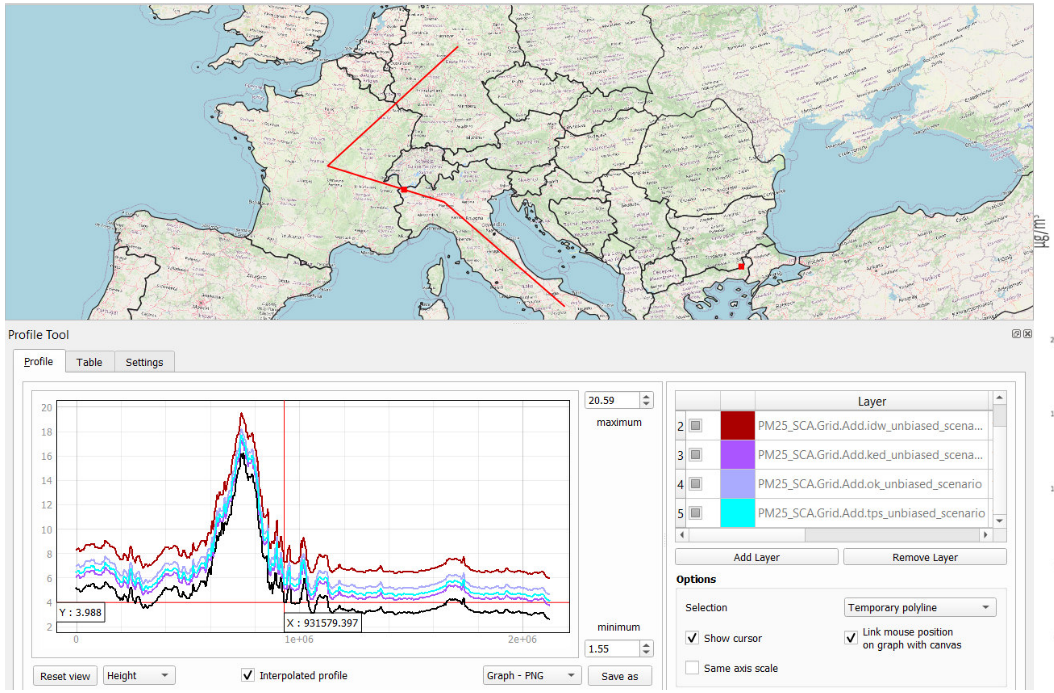


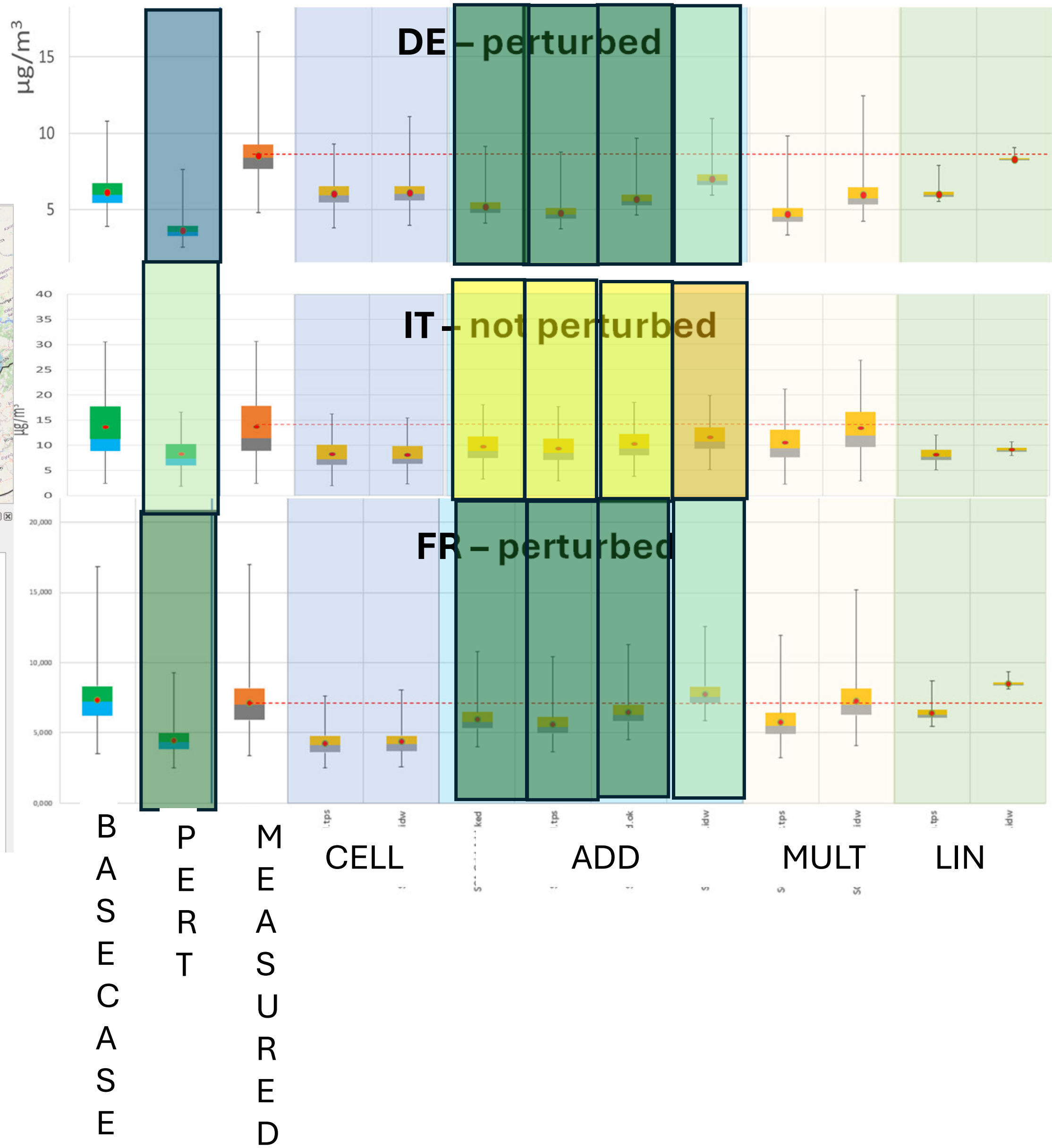


ADD reproduces the SCENARIO distribution

General

Grid.Add.xxx



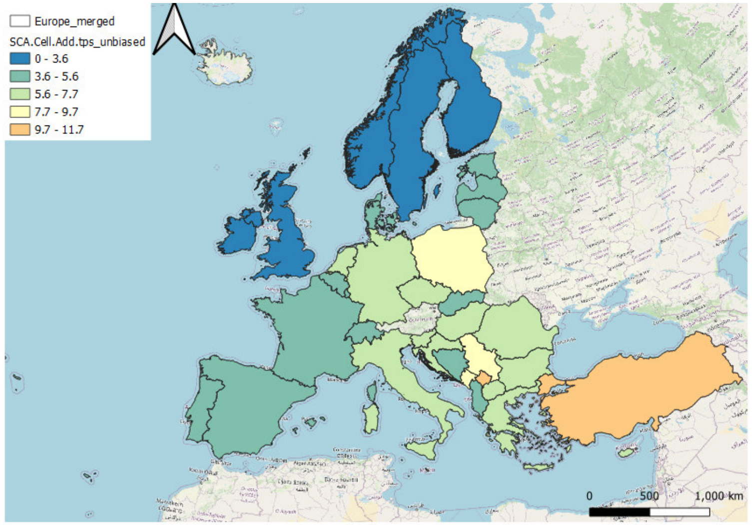


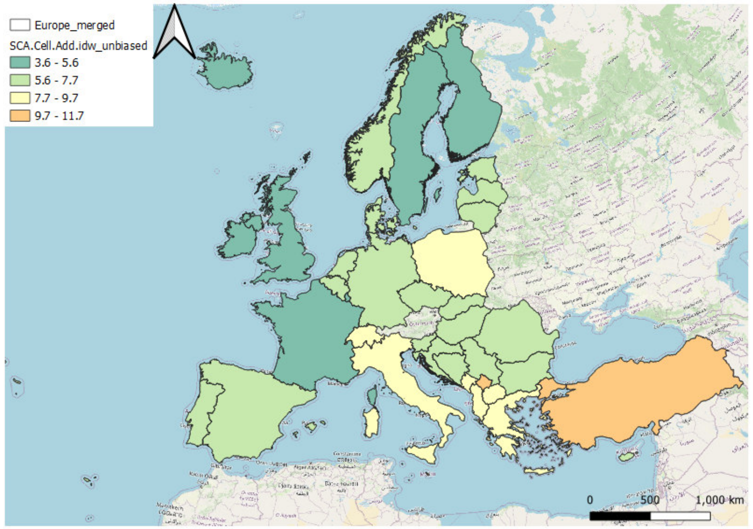
REMARKS:

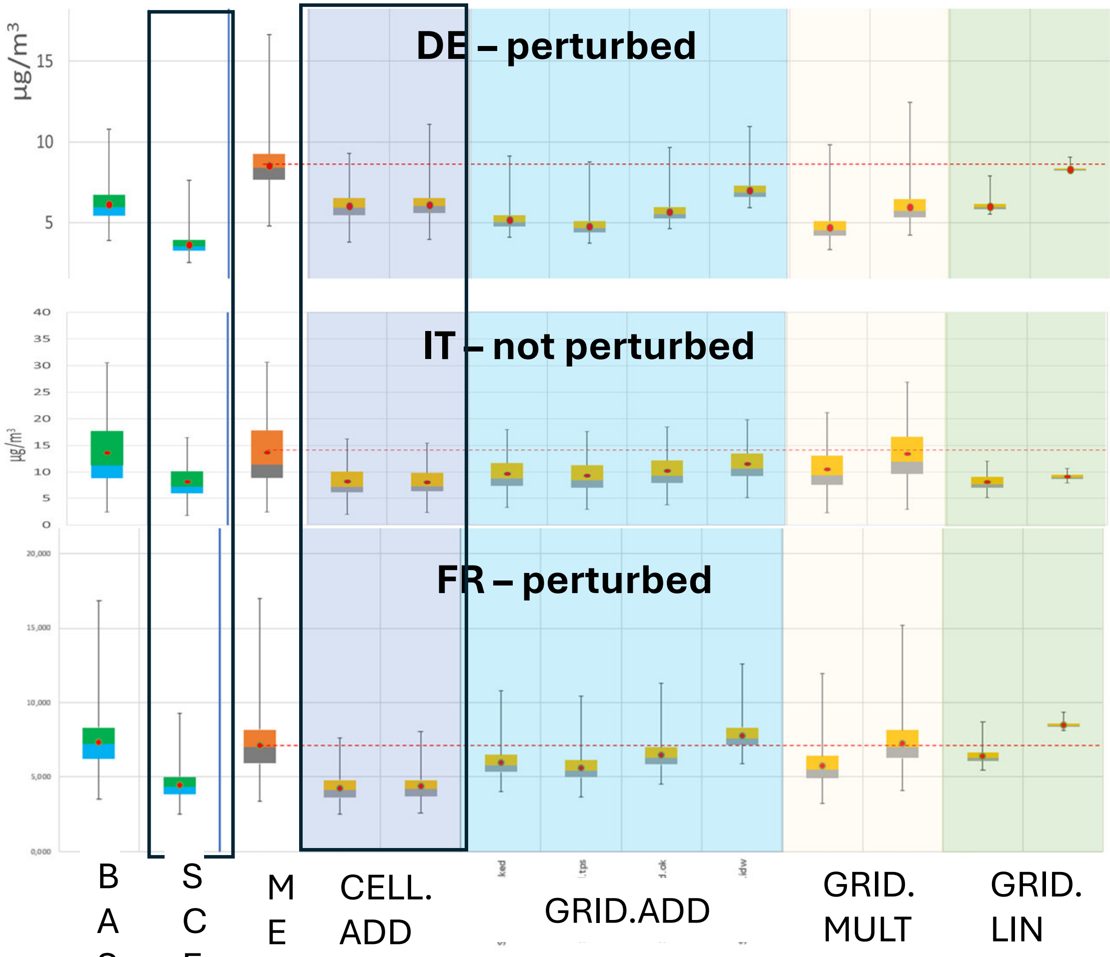
- In general ADD methods are quite similar with narrower values

CELL.ADD

Adds a constant value locally to correct biases.

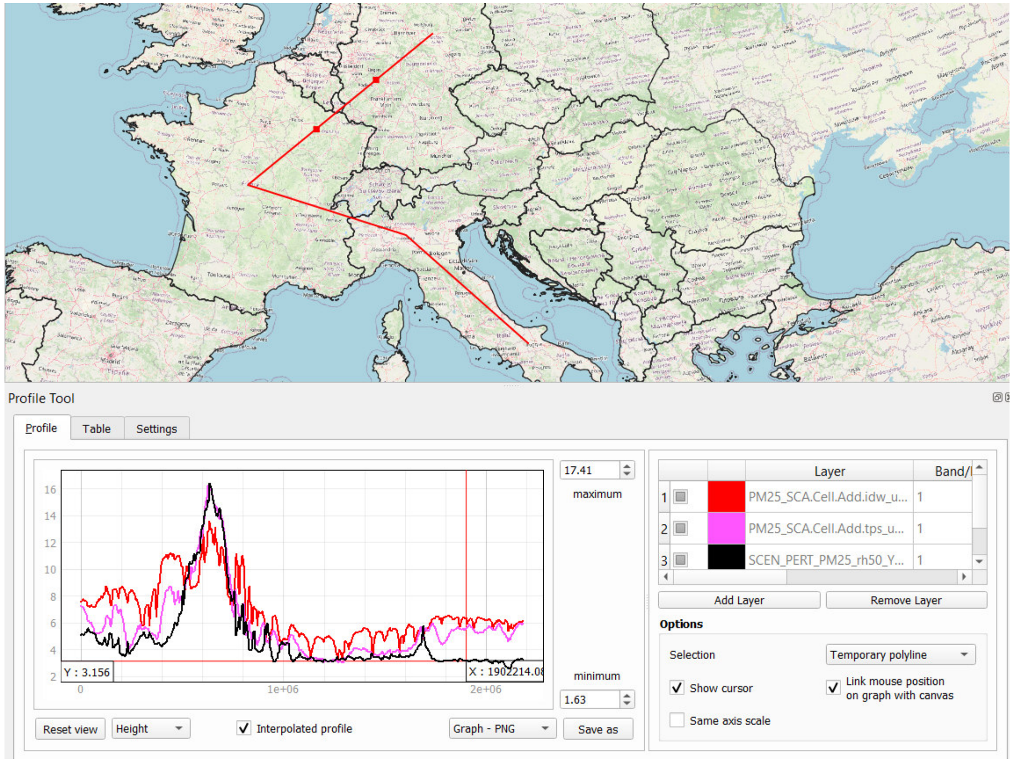


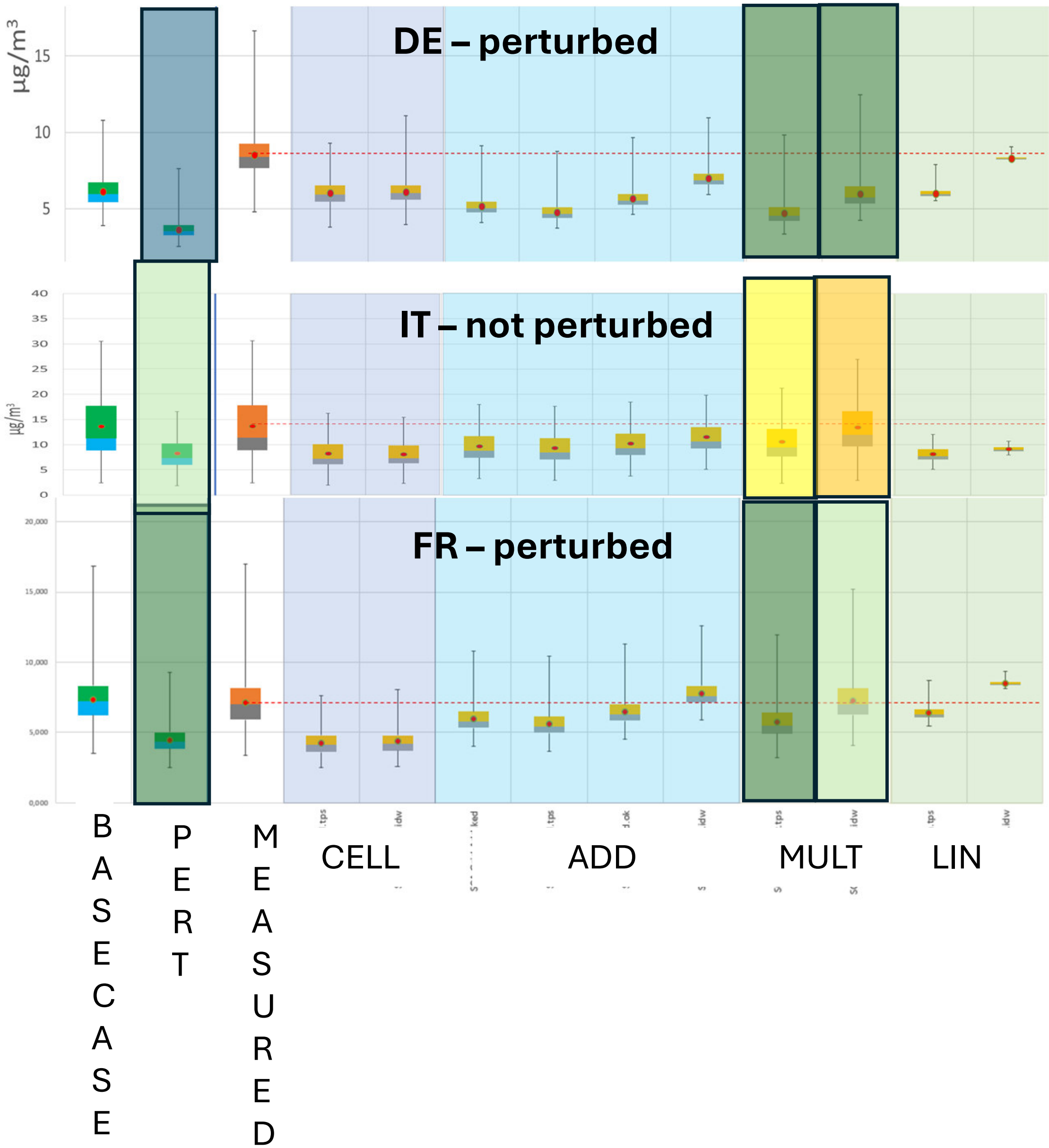




ADD reproduces the SCENARIO distribution and distribution of unperturbated States

Cell.Add.xxx





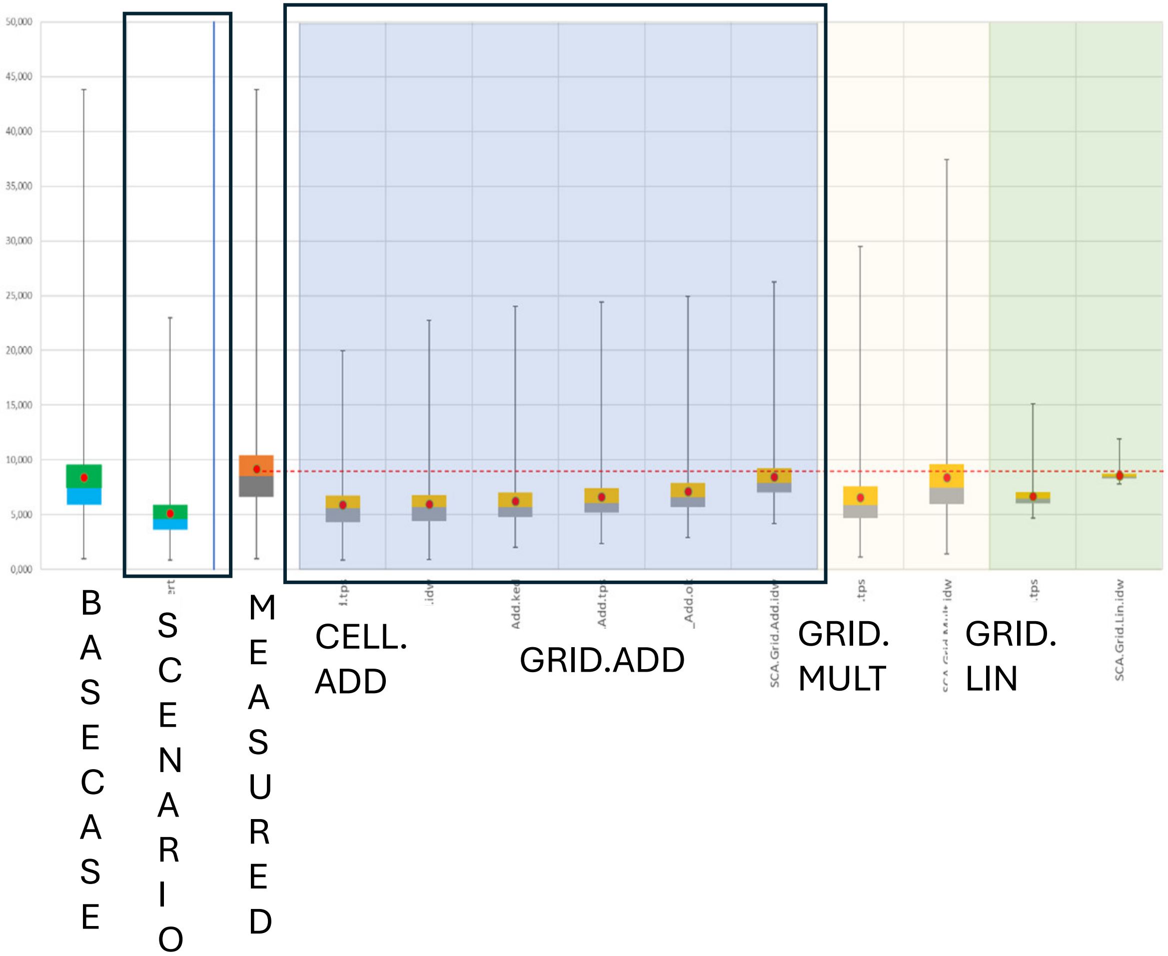
REMARKS:

- In general CELL ADD methods are quite similar with respect to the SCEN pert

General

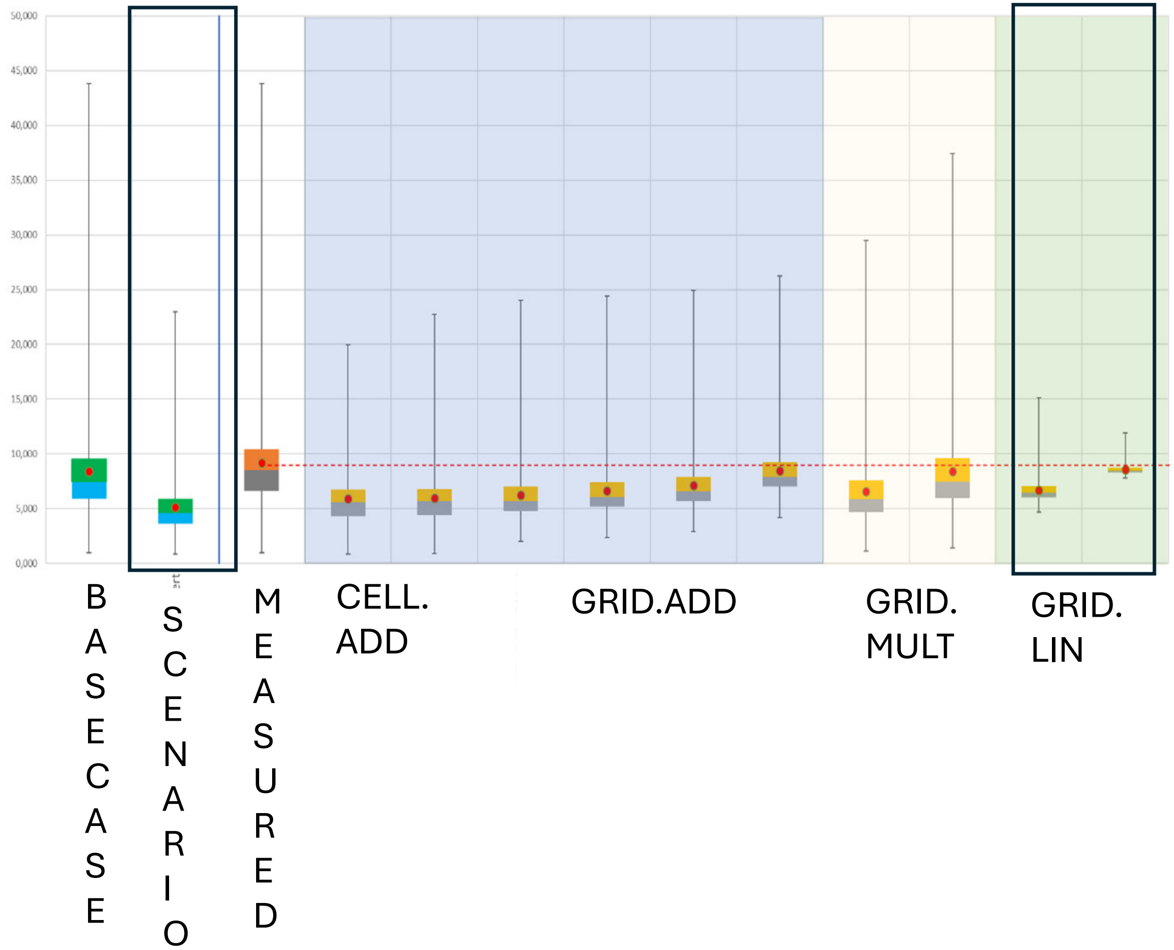
SUMMARY OVERALL EUROPE

- ✓ Additive methods show a similar distribution both among themselves and with perturbed scenarios



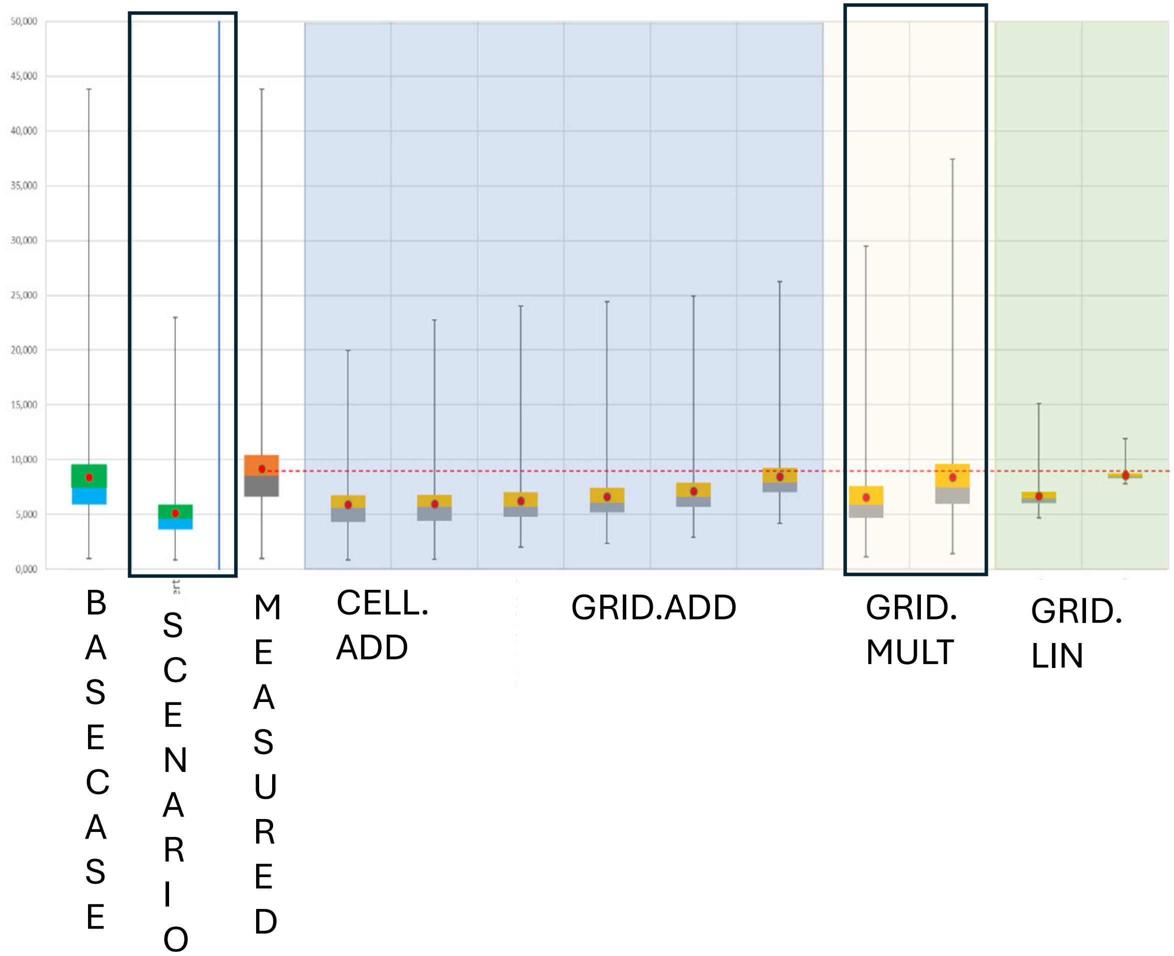
SUMMARY OVERALL EUROPE

- ✓ Additive methods show a similar distribution both among themselves and with perturbed scenarios
- ✓ Linear methods exhibit a compressed distribution with low variability



SUMMARY OVERALL EUROPE

- ✓ Additive methods show a similar distribution both among themselves and with perturbed scenarios
- ✓ Linear methods exhibit a compressed distribution with low variability
- ✓ Multiplicative methods have a distribution similar to the base case and to synthetic measures



So far, we have analyzed the results of 10 methods for PM2.5. There are still 55 more to examine, followed by another 65 for both NO_2 and O_3

CONCLUSIONS

- ✓Results are presented in a «national view» but the analyses consider the entire domain
- ✓The main goal is not to determine whether the method is «correct or not»
- ✓The «sensitivity analysis» may provide insights into the most suitable way to use each method and its limitations
- ✓Further analyses will be conducted to take into account for all possible combination
- ✓In cases like this, where the model errors have opposite signs in different regions of the domain, global corrections—whether additive (grid.add) or multiplicative (grid.mult)—are not suitable because the effects of positive and negative biases cancel each other out

NEXT STEPS

- Awaiting JRC's verdict, based on the «truth not available" 2030 scenario.
- Focusing on the Italian domain, perturbing primary PM, NOx, and NH3 emissions in selected regions. Simulations will be conducted by ENEA using FARM/MINNI.
- Applying more advanced unbiasing methods, particularly for spatialization.
- Given the large number of outputs, we plan to conduct statistical analyses (clustering? PCA? ensemble mixture?).
- Suggestions are welcome!

THANKS FOR YOUR ATTENTION

La statistica è la grammatica della scienza (K. Popper)

Tutti i modelli sono sbagliati, ma alcuni sono utili (Gauss)