

# LIFE-IP MALOPOLSKA

## Action C.6 – International modelling of air pollution in the Małopolska Region, Slovakia and the Czech Republic

Wieliczka, 26<sup>st</sup> February 2020

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VITO: Vranckx, Blyth et al.

# Action C.6 Tasks

## **Task 1: Residential Emission Inventory**

(Lead: VITO, Partners: MZP, SHMU, Malopolska)

## **Task 2: Trans-boundary Emission Data Base**

(Lead: MZP, Partners: VITO, SHMU, Malopolska)

## **Task 3: Inter-regional Air Quality Modelling**

(Lead: MZP, Partners: VITO, SHMU, Malopolska)



# Action C.6 Tasks

## Task 2: Trans-boundary Emission Data Base

(Lead: MZP, Partners: VITO, SHMU, Małopolska)

- Development of **regional benzo[a]pyrene emissions**
- Integration of bottom-up and top-down emissions for a **reference year, 2015**
- Integration of bottom-up and top-down emissions for **emission reduction scenarios**



# Action C.6 Tasks

## **Task 3: Inter-regional Air Quality Modelling**

(Lead: MZP, Partners: VITO, SHMU, Malopolska)

- **Setting up and running CAMx & CMAQ (CTM)**
- **Setting up measurement-based land-use regression model RIO** for near real time and historic air quality assessments
- **Intercomparison of CTM and RIO results**
- **Evaluation of the impact of emission reduction scenarios** by combination of CTM and RIO



# SUMMARY of AIMS

- **Reliable measurement-based model for the description of current air quality** in transboundary region → **RIO**
- CTM model for evaluation of **scenarios**
- **Detailed (& harmonized) emissions** for CTMs
- Combine CTM and RIO to **evaluate expected improvements of air quality according to scenarios**

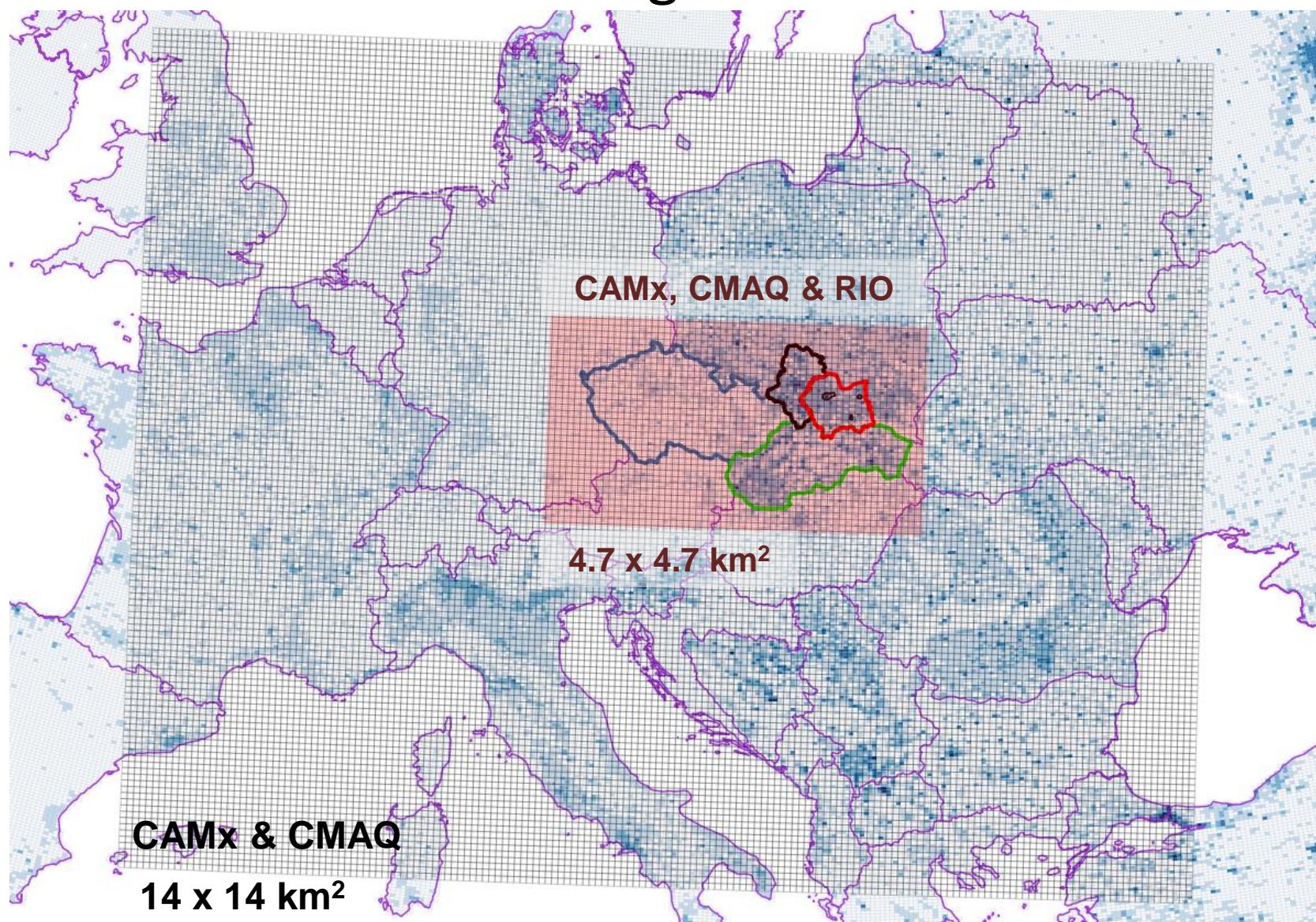


# APPROACH

$$CONC_{SCENARIO} = CONC_{REF} \cdot \frac{CTM_{SCENARIO}}{CTM_{REF}}$$



# Modelling domains



# Transboundary emission inventory

- **Europe** outside of Czech Republic, Poland, and Slovakia:
  - CAMS European anthropogenic emissions v1.1 for 2015
  - **B(a)P** for 2015: J. Bieser from Hamburg University
- **Poland**
  - high-resolution emission inventories for 2015 provided by GIOS (Główny Inspektorat Ochrony Środowiska) and KOBiZE (Krajowy Ośrodek Bilansowania i Zarządzania Emisjami)
- **Małopolska and Silesia** Regions
  - residential heating emissions for 2015 provided by ATMOTERM (to be consistent with AQP scenarios)



# Transboundary emission inventory

- Czech Republic

- Czech national inventory REZZO (2015) (point sources, residential heating, technologies, agriculture), road and off-road transport emissions (2016), emissions from Václav Havel Airport Prague (2016).
- unreported fugitive emissions corresponding to 2017: production of coke, iron and steel (aggl. O/K-F-M, near border with Silesia), smelting works (whole territory of CR), other sources in aggl. O/K/F-M, and quarries (whole territory of CR).



# Transboundary emission inventory

- Slovakia

- detailed residential heating emissions and point sources that belong to SNAP 2 (2015). The rest of emissions: CAMS 2015.

- Biogenic emissions

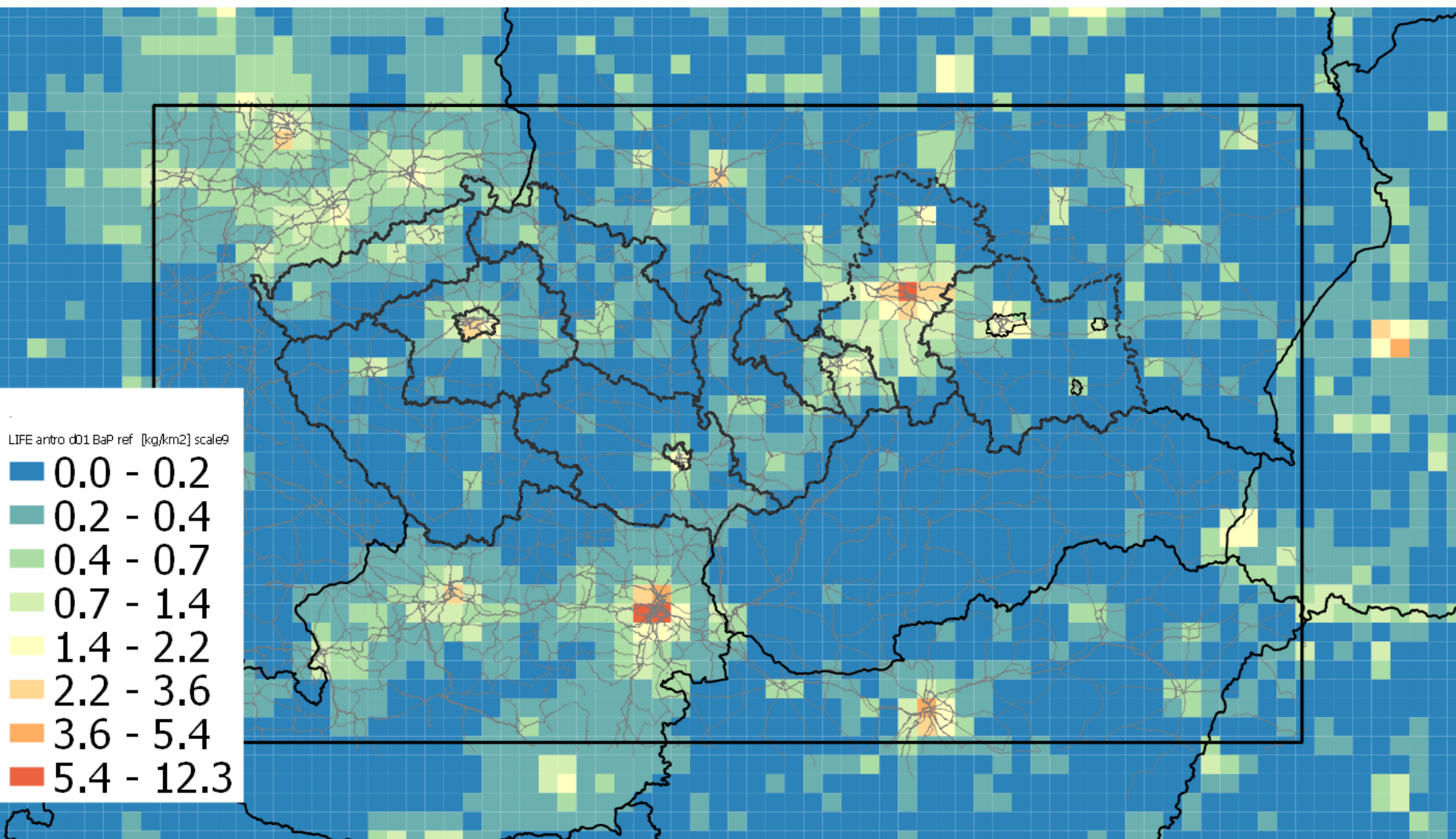
- Biogenic emissions were calculated by the MEGAN model based on the meteorology from the numerical weather prediction model (ALADIN/WRF).

Residential heating (CZ, SK) – boiler operation conditions 85/15:

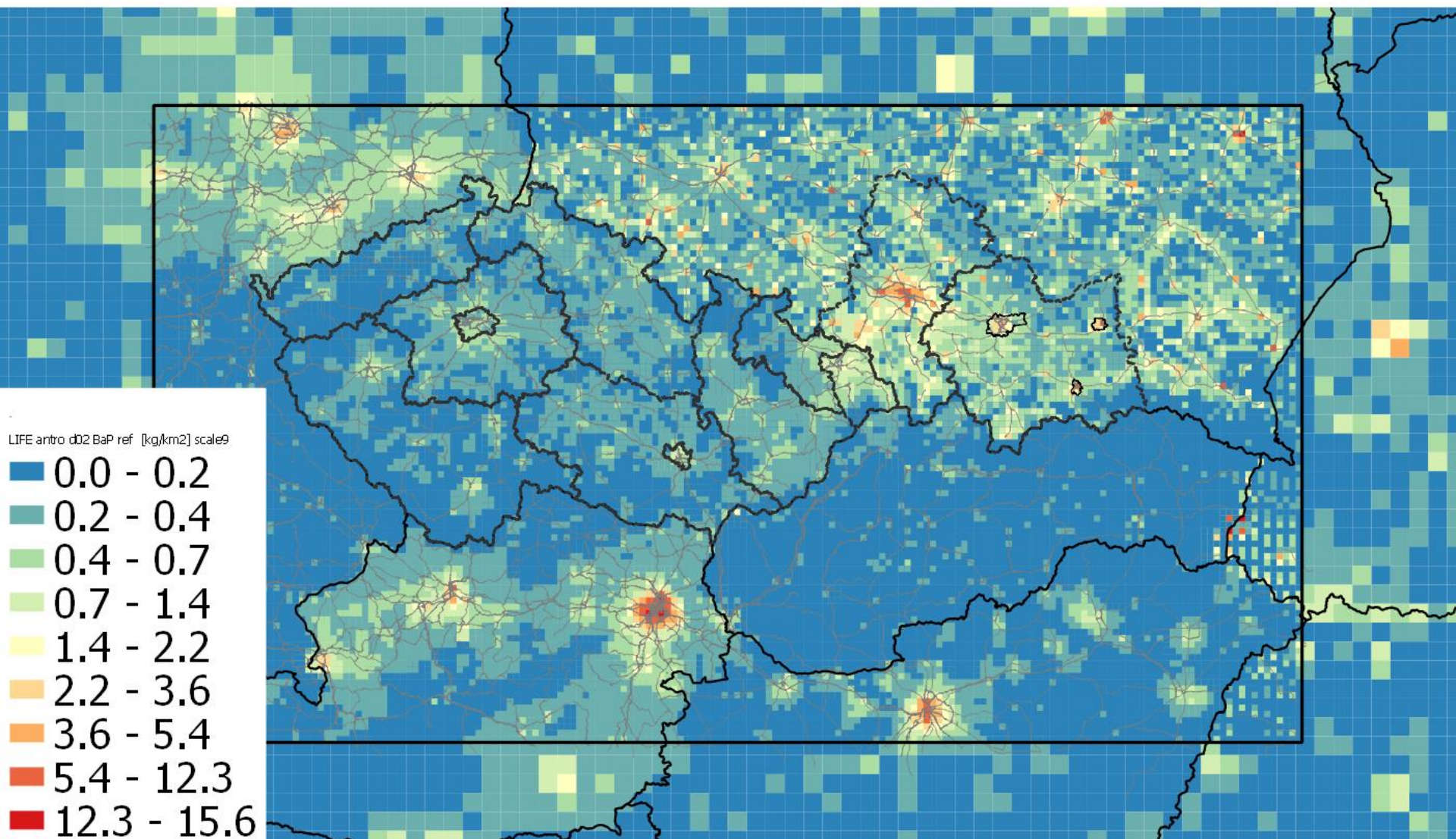
- 15% time nominal heat output
- 85% time lower heat output



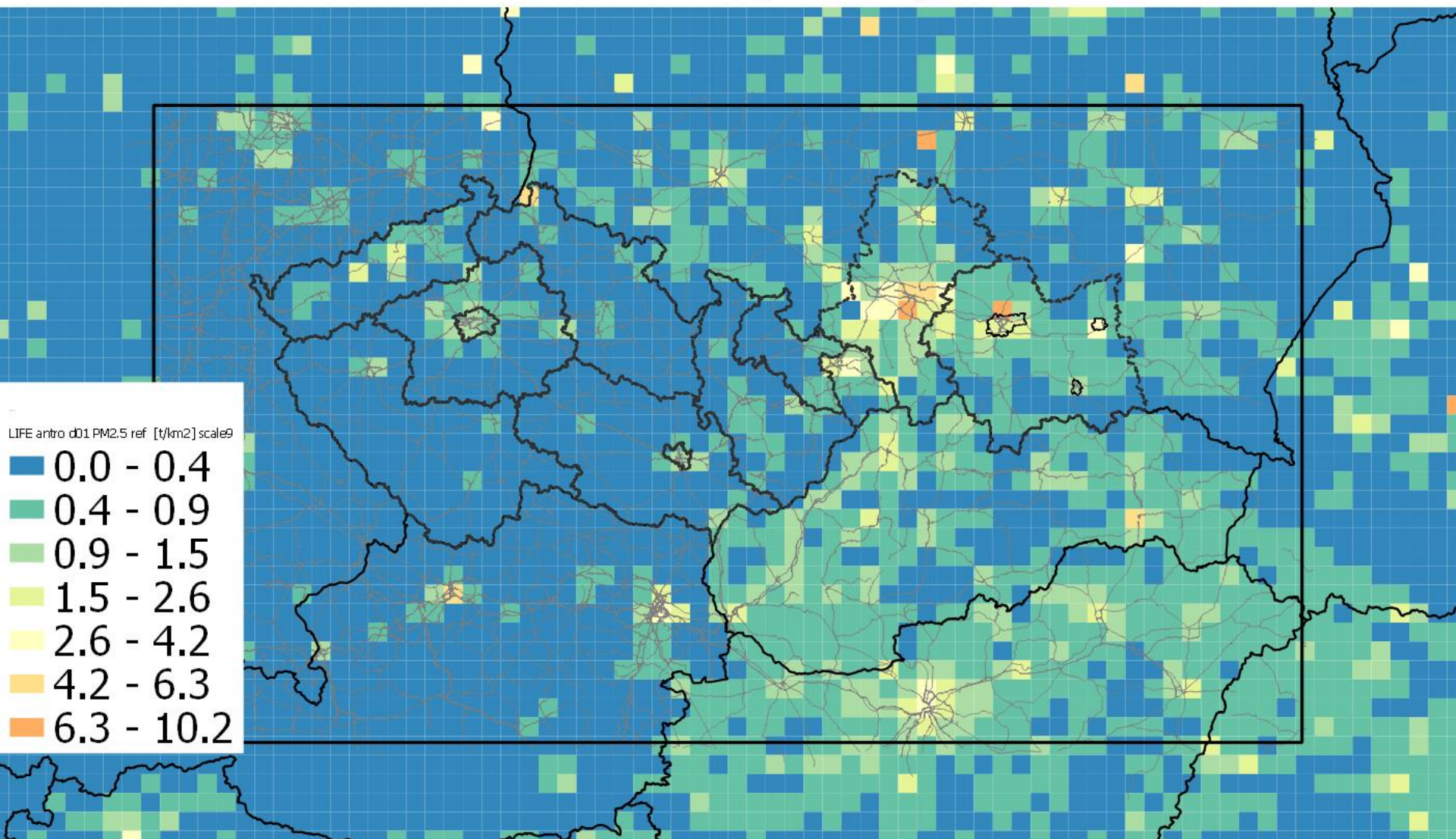
# B[a]P annual emissions (J. Bieser, LIFE-IP MP) 2015 ref [kg.km<sup>-2</sup>]



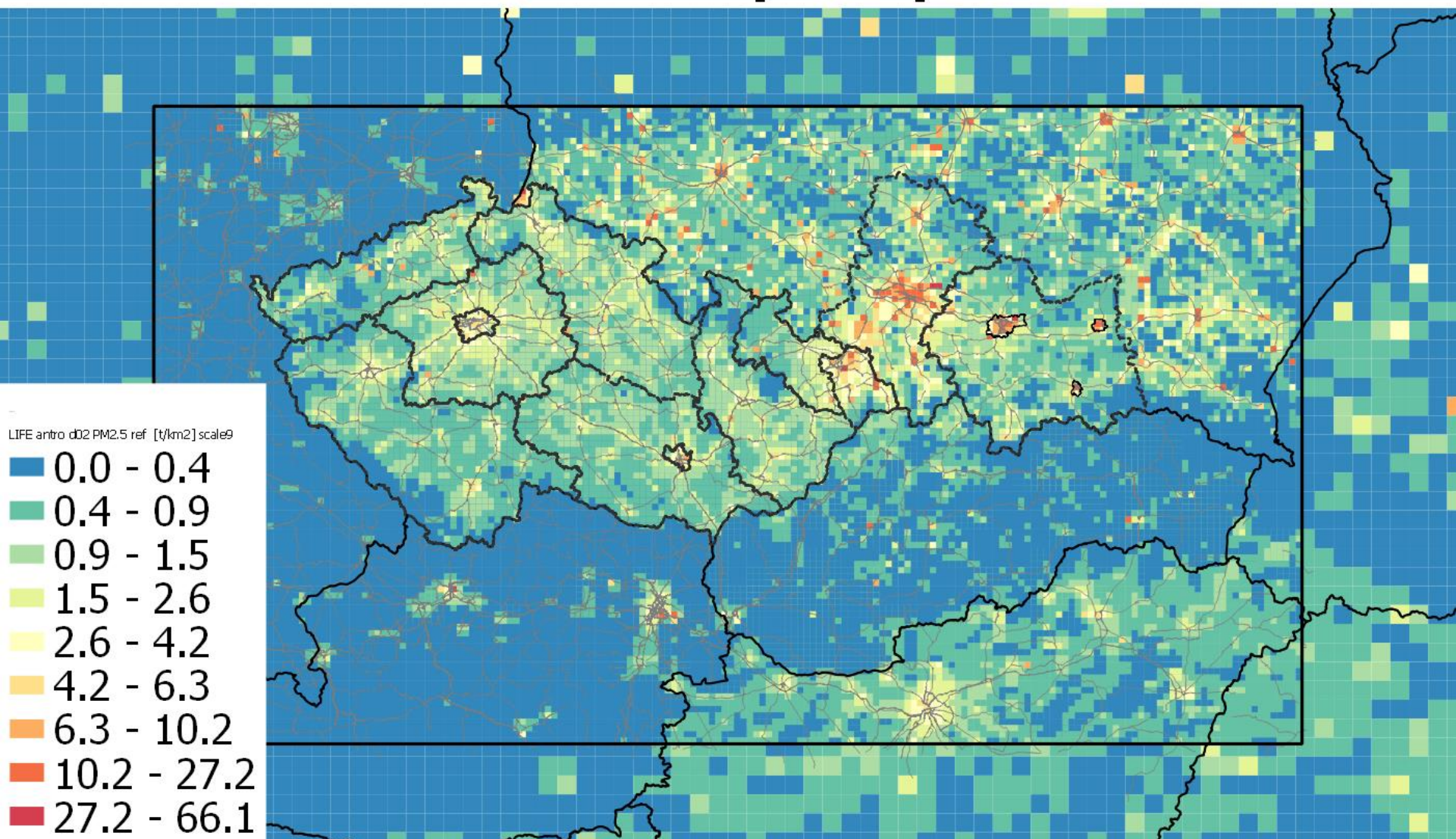
# B[a]P annual emissions (anthropogenic) 2015 ref [kg.km<sup>-2</sup>]



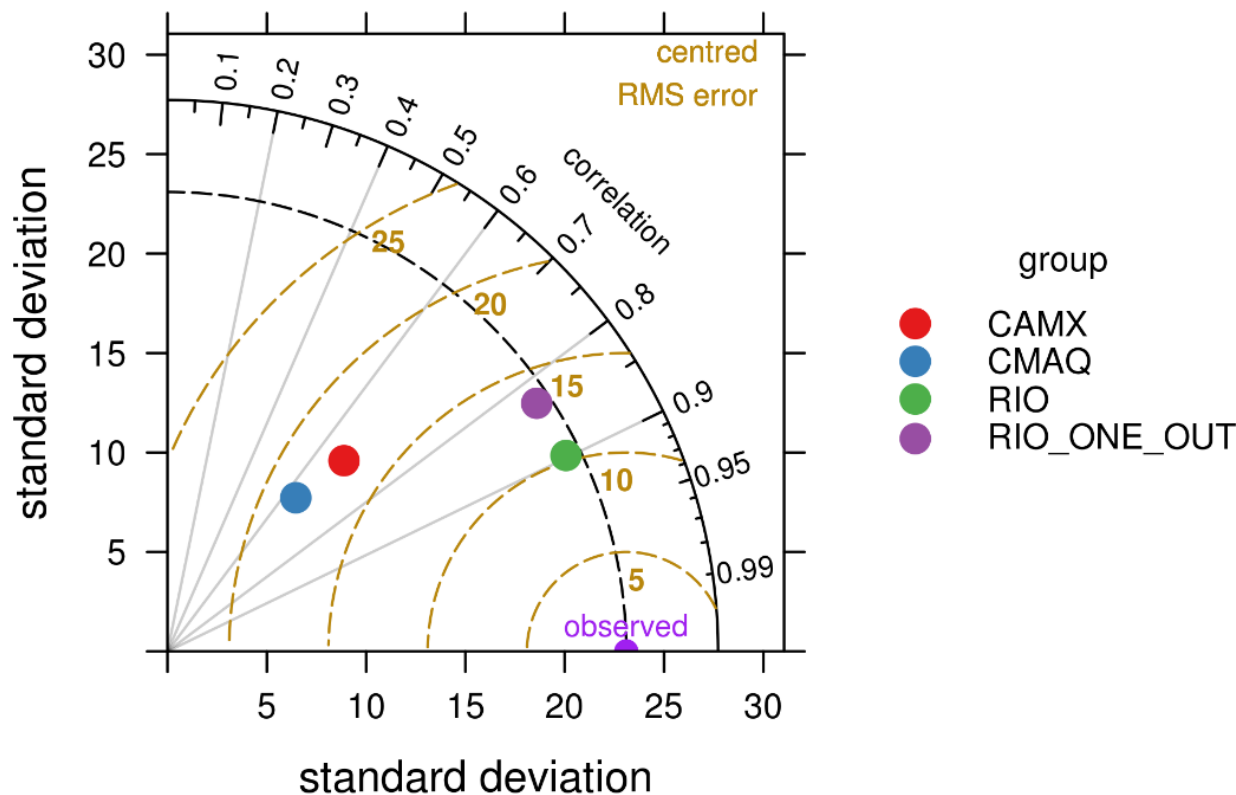
# PM<sub>2.5</sub> annual emissions (CAM5-REGv1.1-AP) 2015 ref [t.km<sup>-2</sup>]



# PM<sub>2.5</sub> annual emissions (anthropogenic) 2015 ref [t.km<sup>-2</sup>]

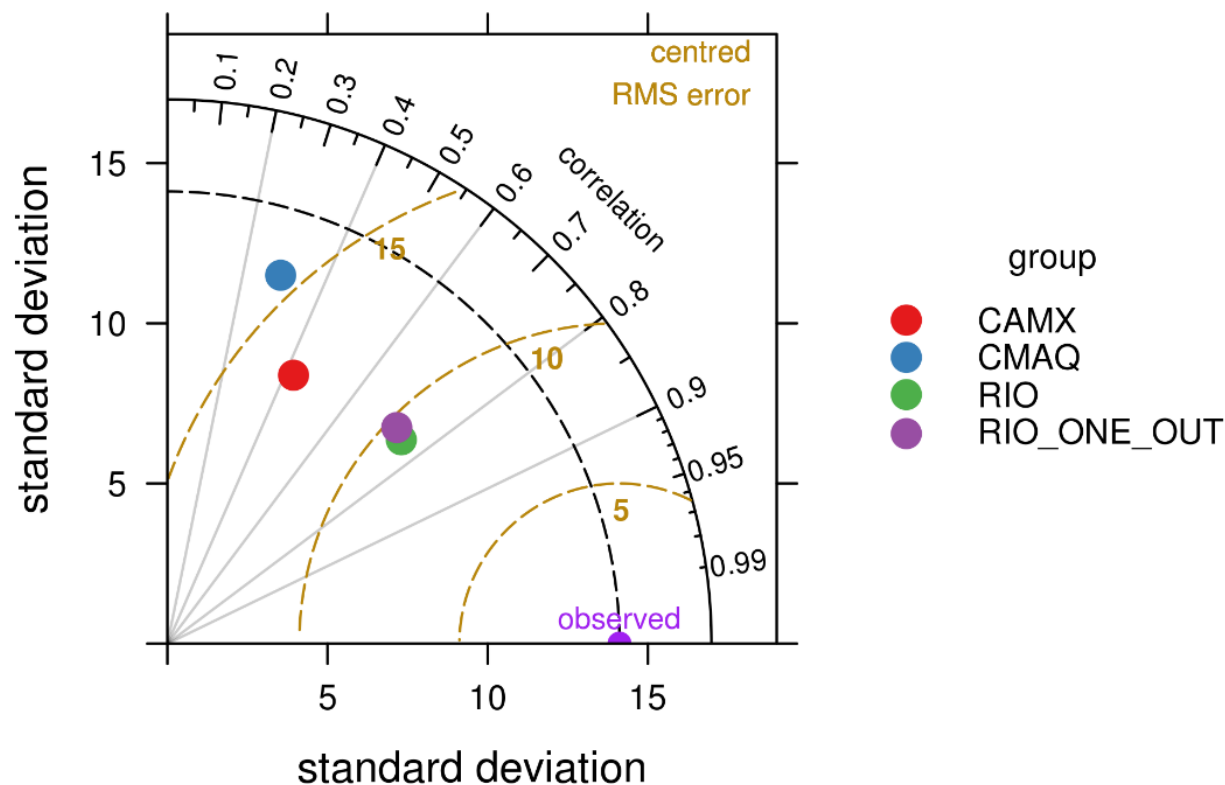


# Model validation $PM_{10}$



Taylor diagram for comparison CAMX and CMAQ, RIO and RIO\_out for  $PM_{10}$  with daily measured data from all Czech, Poland and Slovak monitoring stations in 2015

# Model validation $\text{NO}_2$



Taylor diagram for comparison CAMX and CMAQ, RIO and RIO\_out for  $\text{NO}_2$  with daily measured data from all Czech, Poland and Slovak monitoring stations in 2015

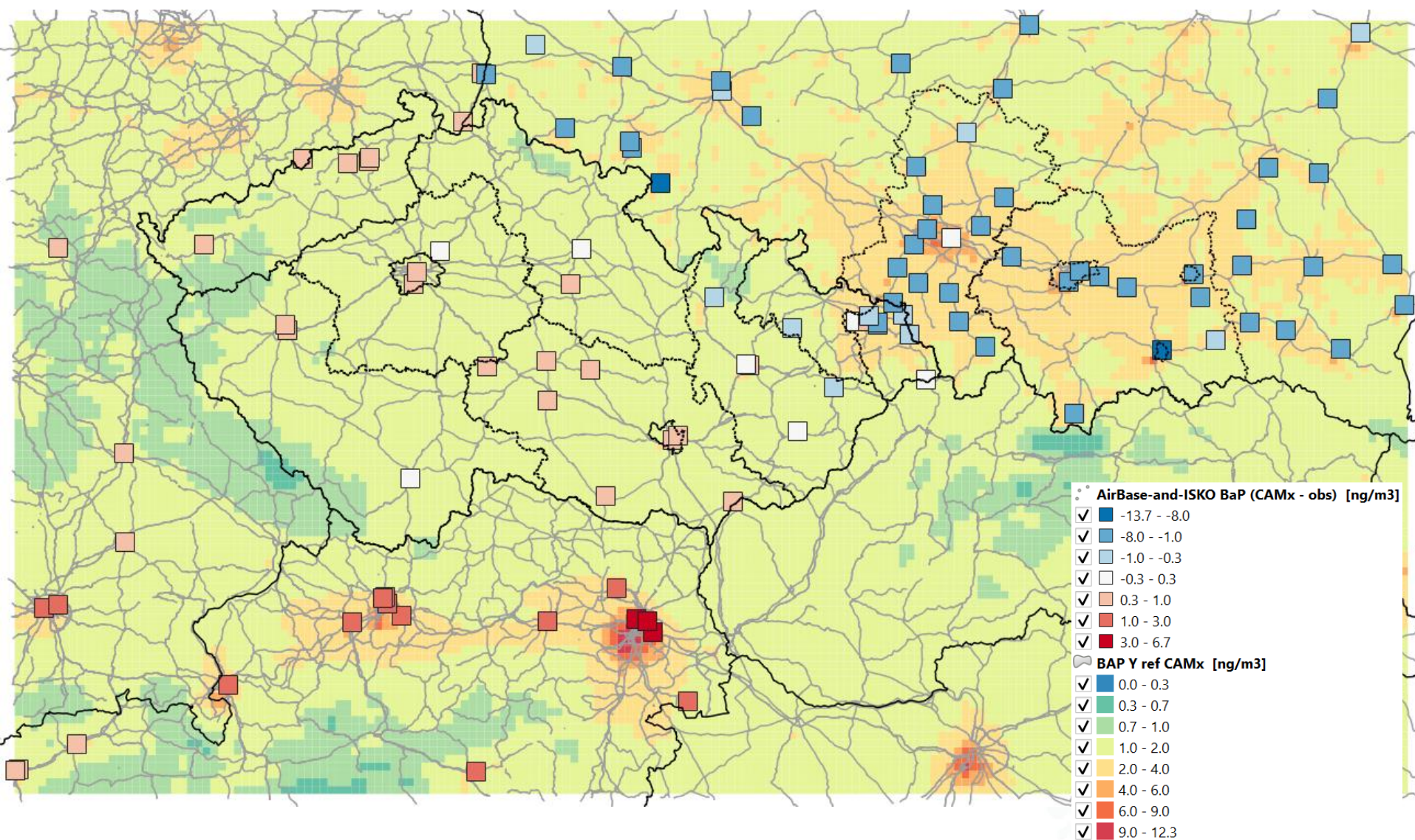
## Model validation B(a)P

Model	FAC2	MB	NMB	r
CAMX	0.39	-1.93	-0.40	0.55
CMAQ	0.17	-4.24	-0.86	0.47

Comparison the CAMX and CMAQ, with daily measured data of **benzo(a)pyrene** from rural background Czech, Poland, Austria, Hungary and Slovak monitoring stations in 2015



# Model validation B(a)P



# 2023 scenarios

**Business as usual (BAU) =**  
= without additional measures contained in AQP

**Optimistic =**  
= implementation of measures in AQP



# 2023 scenarios - Małopolska

## Assumptions wrt 2015

- decrease of heat demand due to thermal modernization and new building development (0.95)
- change in the use of wood:
  - Cities – 0.6
  - Krakow – 0
  - Nowy Sącz – 0.4
  - Tarnów – 0.3
  - the rest of the region – 0.75
- waste incineration: 0.9 in **BAU** and zero in "**optimistic**"



# 2023 scenarios - Małopolska

## Assumptions wrt 2015

- Reduction of energy from solid fuels (wood and coal; 1 corresponds to total reduction) for Małopolska scenarios

Region	BAU	“optimistic”
cities	0	0.3
Krakow	1	1
Nowy Sącz	0	0.3
Tarnów	0	0.3
the rest of the territory	0	0.05



# 2023 scenarios - Małopolska

## Assumptions wrt 2015

- Emission classes of solid fuel boilers

Scenario	Existing boilers	New boilers until 2019	New boilers since 2020 incl.
<b>BAU</b>	manual, without emission class	automatic boilers, without emission class	automatic boilers, Ecodesign
<b>“optimistic”</b>	manual, Ecodesign	automatic boilers, Ecodesign	

*Further details in 2017 AQP*

# 2023 scenarios - Małopolska

## Optimistic

		Valid from
<b>Solid fuel boilers</b>	<b>Compulsory class:</b> Ecodesign	
	Old boilers	2023
	New boilers without class specification	2023
	New boilers class 3/4	2027
	Purchase of new boilers after the program comes into force	July 2017
<b>Fireplaces</b>	<b>Requirements:</b> Ecodesign, efficiency > 80%, particle filter	
	Existing facilities	2023
	New facilities	July 2017
<b>Solid fuels</b>	<b>Limitations</b>	
	Coal	No sludge, flocculates, or fuels with 0–1 mm grain size
	Biomass	Humidity must be below 20%

*Further details in 2017 AQP*

## 2023 scenarios - Silesia

1. **BAU** - extrapolation of annual municipality emission changes in years 2015–2017 (anti-smog resolution has not yet taken effect).
2. **“optimistic”** – Silesia 2017 AQP (**40% of the total emission reduction expected in 2027**)
  - 2015–2017 extrapolation has great uncertainty
  - 2027 scenario - most substances needed by CTM missing
  - **steps 1. and 2. were done for PM<sub>10</sub> only**
  - **changes of other pollutants determined for each municipality according to PM<sub>10</sub> reductions and change in emissions of a given substance that can be expected in a unit change in PM<sub>10</sub> emission according to Małopolska AQP**

## 2023 scenarios - Silesia

- Silesian emissions for the “optimistic” 2023 scenario and their reduction compared to the reference year 2015. Emissions from the Silesian Voivodeship Air Protection Program (40% reduction planned in 2027) and emissions calculated on the basis of PM<sub>10</sub> emission reduction are presented.

	Emissions [t]		Reduction of emissions wrt 2015 [%]	
	Silesian Air Protection Program	recalculation according to PM <sub>10</sub>	Silesian Air Protection Program	recalculation according to PM <sub>10</sub>
<b>PM<sub>2.5</sub></b>	14 820	13 761	23	28
<b>B[a]P</b>	6.751	5.969	23	32

## 2023 scenarios – Czech Rep.

Both BAU and optimistic: part of the family houses would switch from solid fuel to natural gas:

- municipalities < 10 000 inhabitant – 10 % of family houses
- municipalities > 10 000 inhabitants – 20 % of family houses
- proportion of households using coal and biomass remained unchanged.
- valid only if there were at least 10 households in the municipality, which were heated by natural gas, otherwise the ratio of households between natural gas and solid fuels remained unchanged.



## 2023 scenarios – Czech Rep.

- family houses using solid fuels would convert to emission-free heating sources: BAU 5 %, optimistic 15 %
- **optimistic: compliance with legislative requirements** (solid fuel boilers meet the limits of min. emission class 3). 30 out of 186 thousand of boilers with down-draft combustion and all of over-fire boilers (326 thousand in 2018), except for those in which coke was burned, were replaced.
- **BAU:** boiler replacement requirements would not be met and a large proportion of old boilers would still be in operation (only 90 thousand of over-fire boilers and boilers with down-draft combustion were replaced by automatic and gasification boilers)



# 2023 scenarios - Slovakia

- The emission reduction scenarios for Slovakia are based on the proposals in the Air Protection Strategy of Slovak Republic, prepared by the Ministry of the Environment based on the World Bank Reimbursable Advisory Services project results.

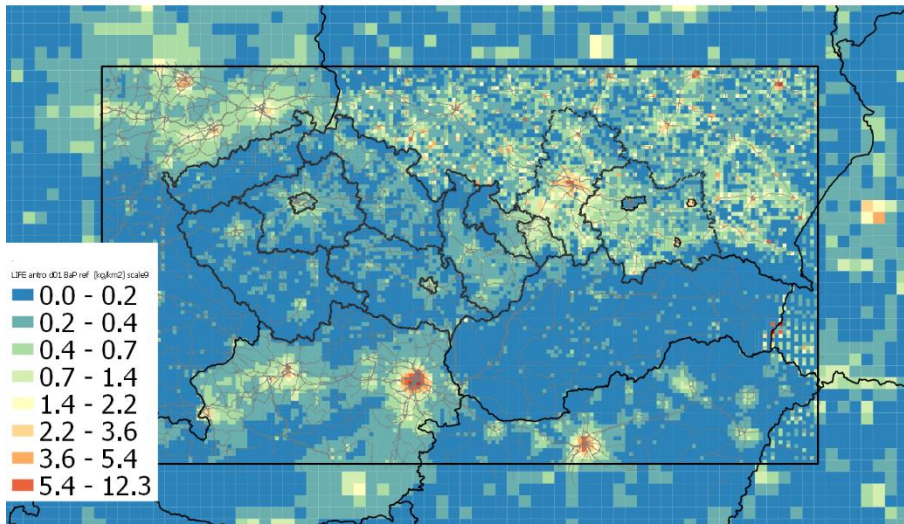


# 2023 scenarios

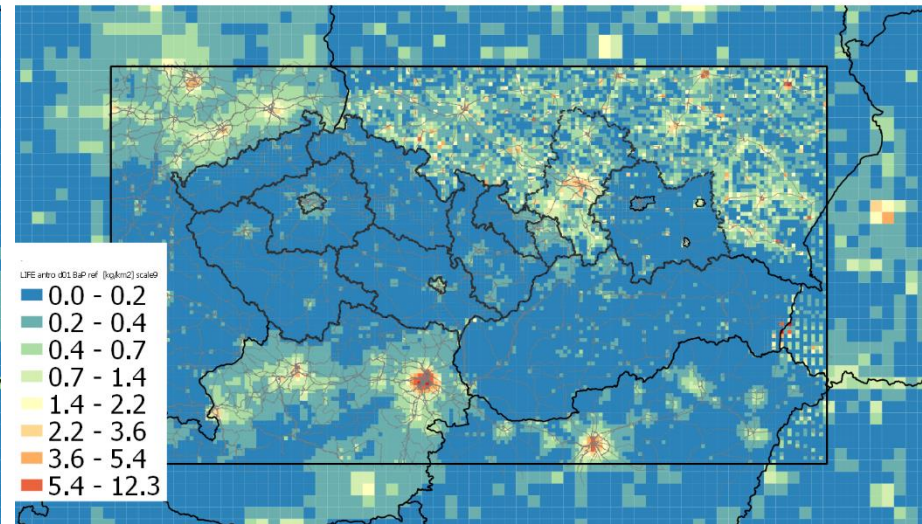
inventory / emissions [t]	SO <sub>2</sub>	NO <sub>x</sub>	NH <sub>3</sub>	CO	NMVOC	BZN*	BAP	PM <sub>10</sub>
scenario / ref								
CZ 2023 BAU	0,86	1,00	1,03	0,82	0,81	0,83	0,82	0,79
CZ 2023 opt	0,78	0,97	0,92	0,58	0,51	0,48	0,39	0,39
PL_MP 2023 BAU	0,86	1,14	0,51	0,83	0,83		0,85	0,80
PL_MP 2023 opt	0,01	1,61	0,27	0,10	0,05		0,15	0,08
PL_SL 2023 BAU	0,93	1,06	0,70	0,89	0,89	1,00	0,86	0,88
PL_SL 2023 opt	0,80	1,11	0,79	0,77	0,75	1,00	0,68	0,77
SK 2023 BAU	0,85	0,84		1,00	1,00	1,00	1,00	0,85
SK 2023 opt	0,41	0,79		1,00	1,00	1,00	1,00	0,84



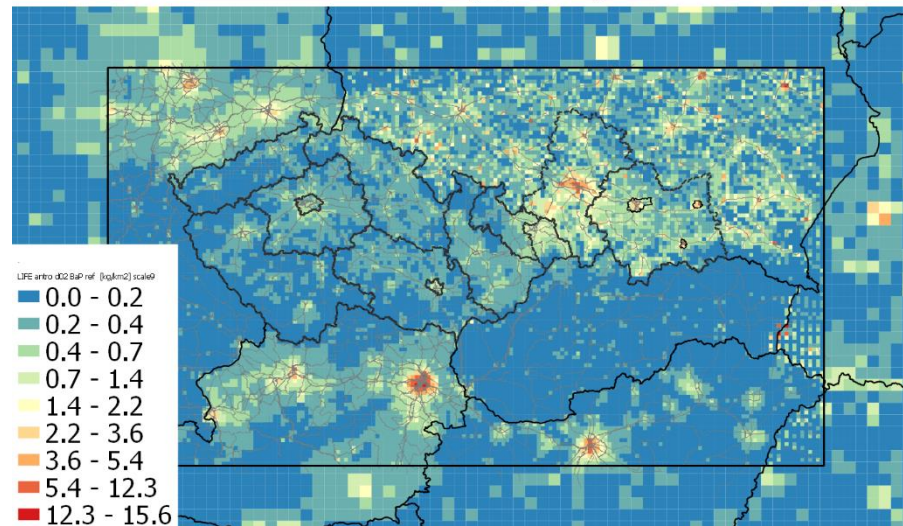
**B[a]P annual emissions (anthropogenic)**  
**2023 BAU** [kg.km<sup>-2</sup>]



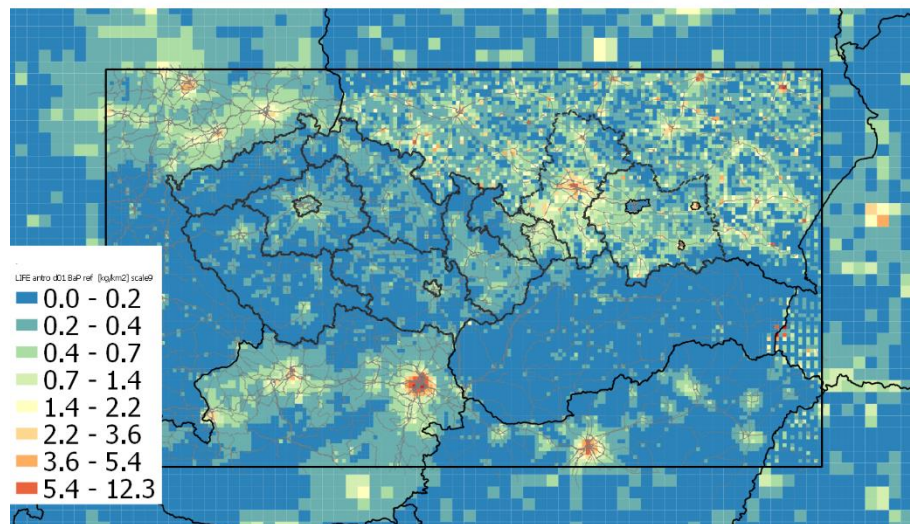
**B[a]P annual emissions (anthropogenic)**  
**2023 optimistic** [kg.km<sup>-2</sup>]



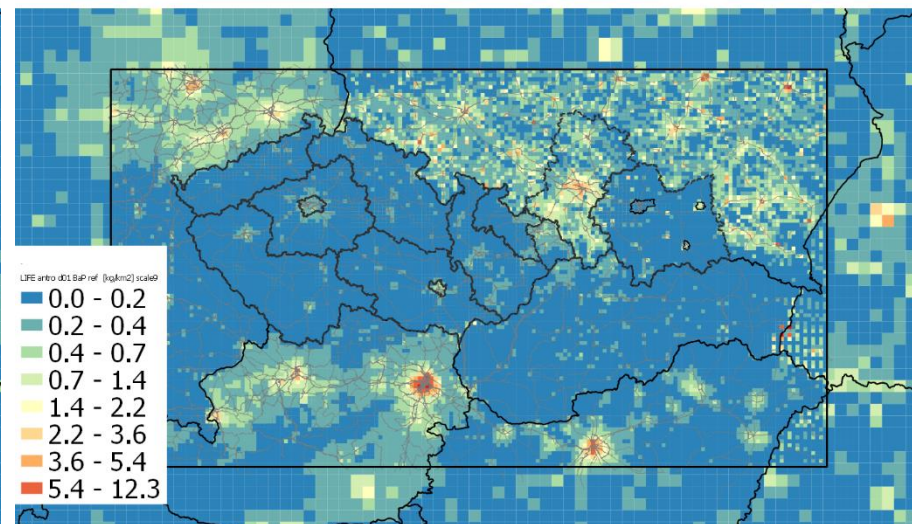
**B[a]P annual emissions (anthropogenic)**  
**2015 ref** [kg.km<sup>-2</sup>]



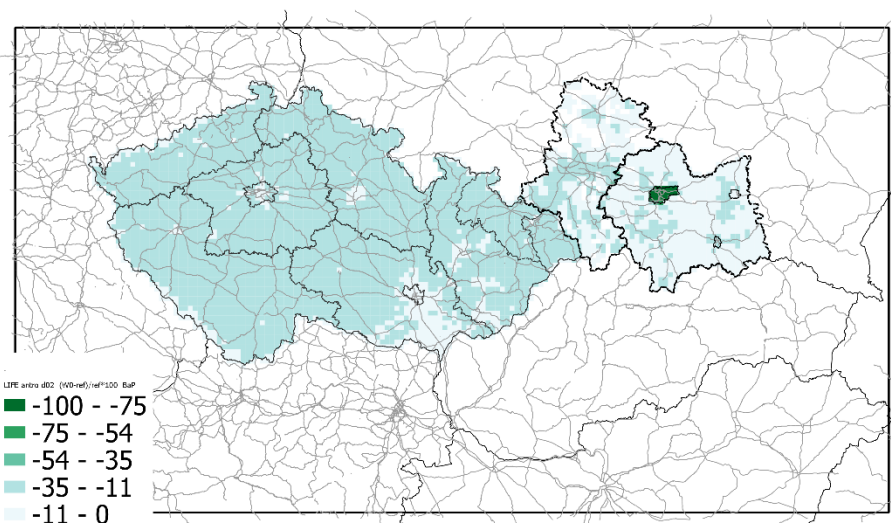
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2023 BAU [kg.km<sup>-2</sup>]



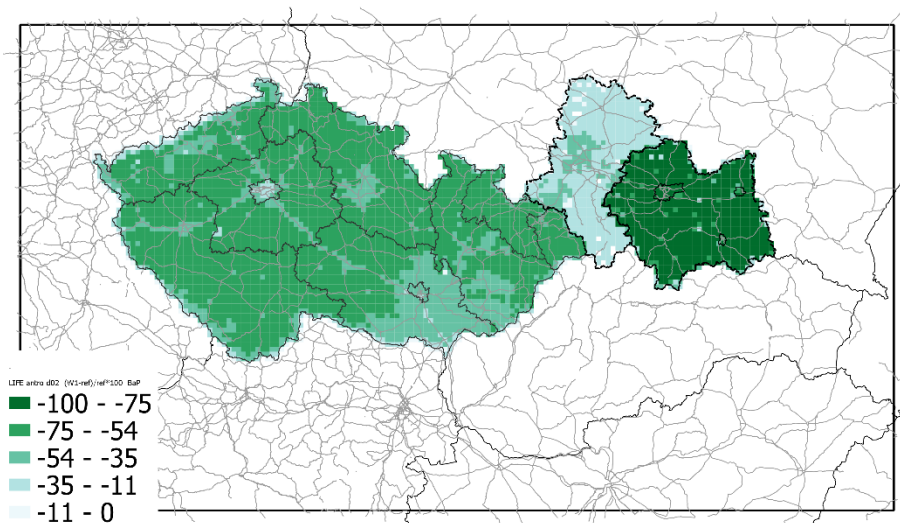
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2023 optimistic [kg.km<sup>-2</sup>]



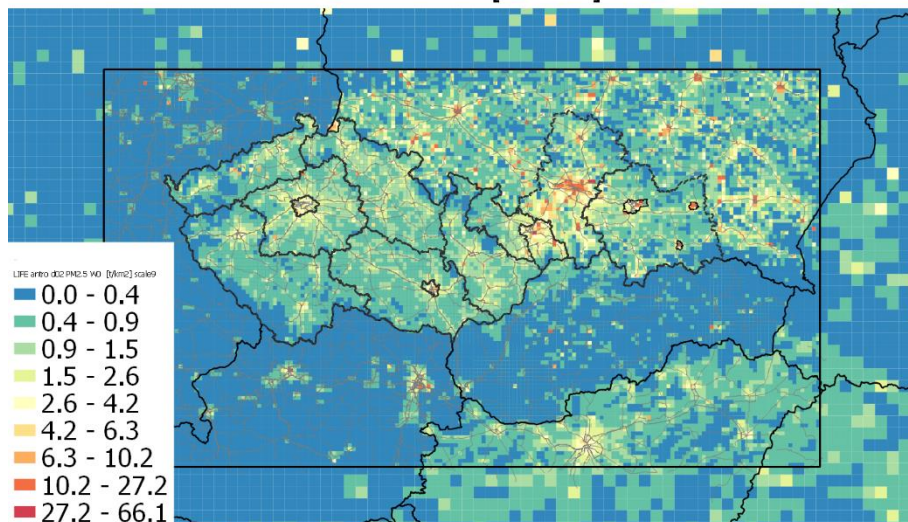
**Relative change of B[a]P annual emissions**  
 $100 \cdot (2023 \text{ BAU} - 2015 \text{ ref}) / 2015 \text{ ref}$  [%]



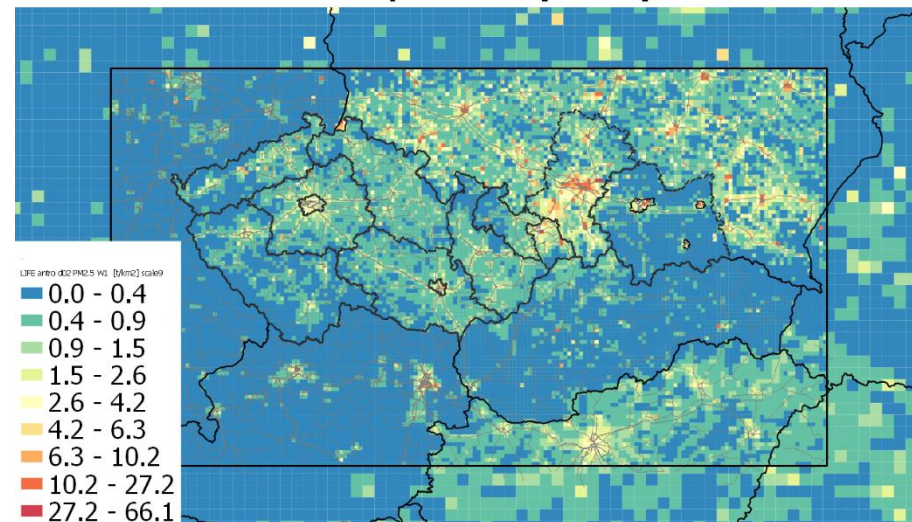
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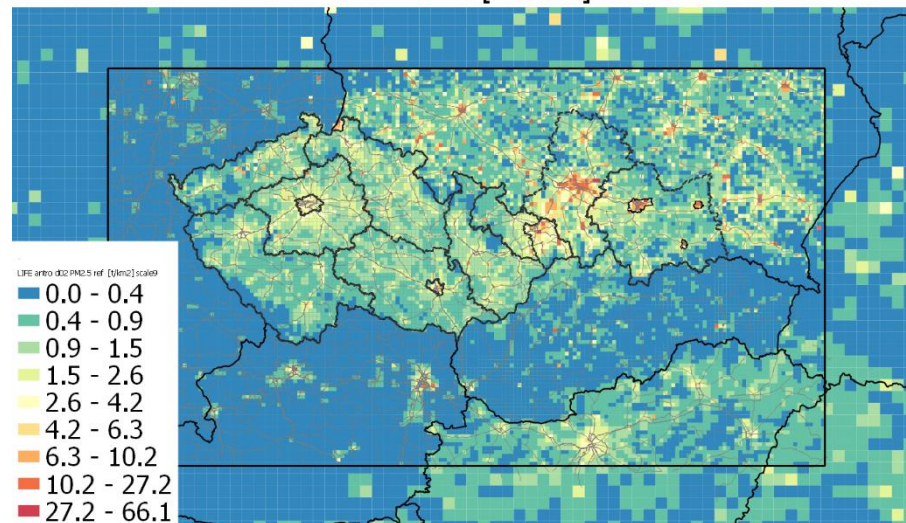
PM<sub>2.5</sub> annual emissions (anthropogenic)  
2023 BAU [t.km<sup>-2</sup>]



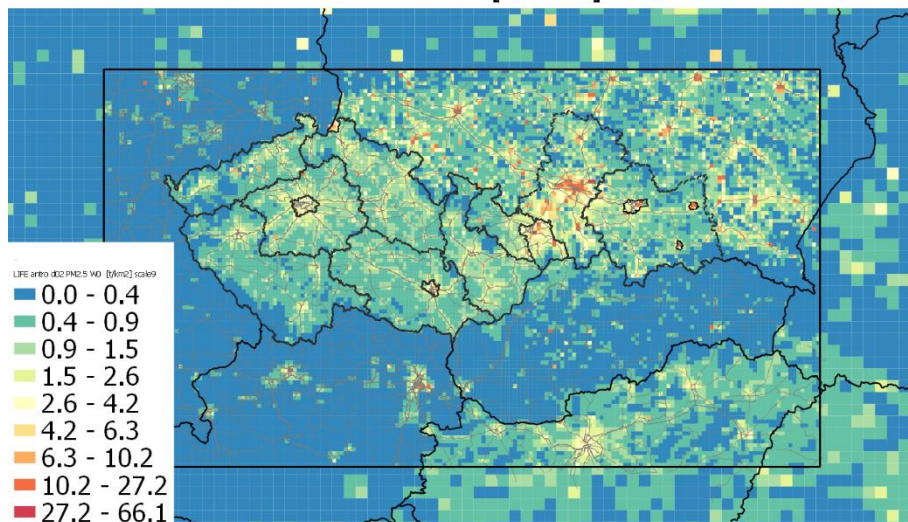
PM<sub>2.5</sub> annual emissions (anthropogenic)  
2023 optimistic [t.km<sup>-2</sup>]



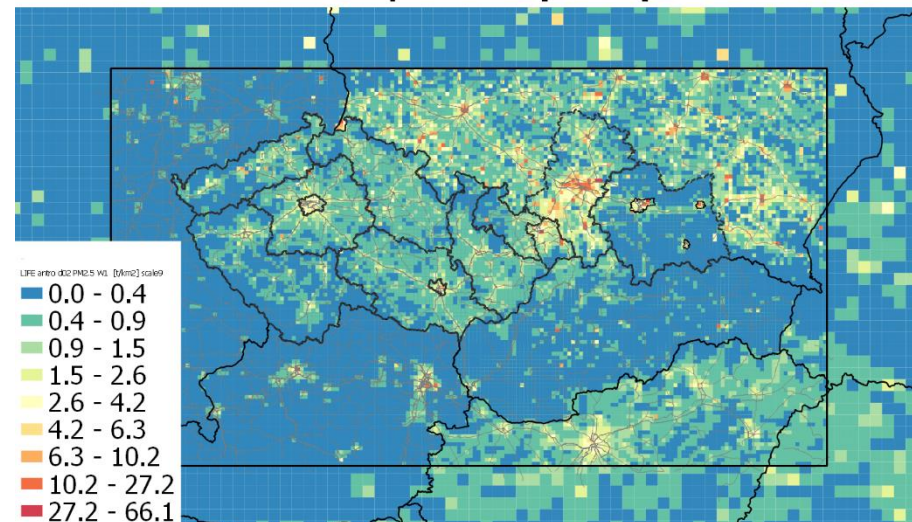
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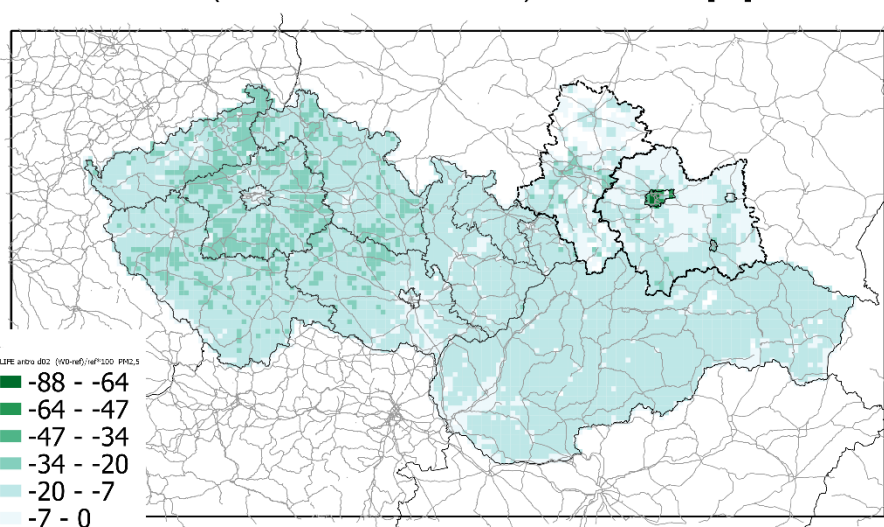
PM<sub>2.5</sub> annual emissions (anthropogenic)  
2023 BAU [t.km<sup>-2</sup>]



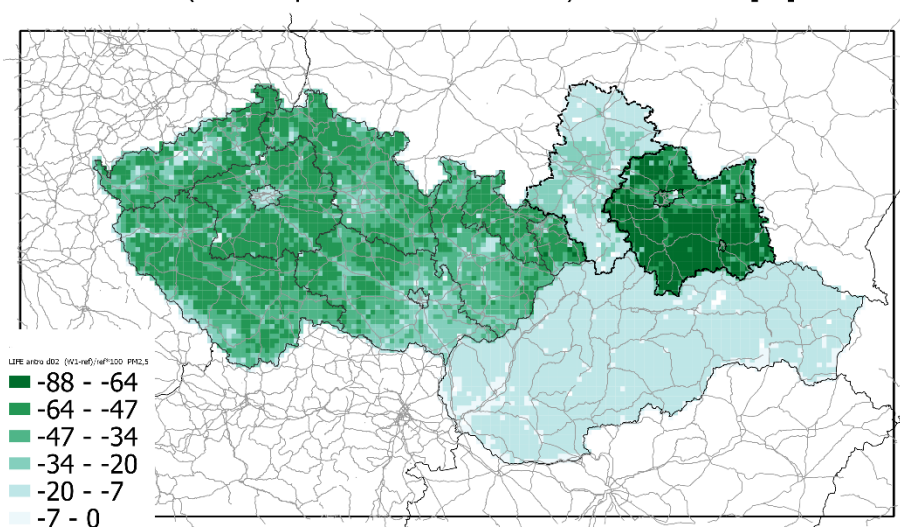
PM<sub>2.5</sub> annual emissions (anthropogenic)  
2023 optimistic [t.km<sup>-2</sup>]



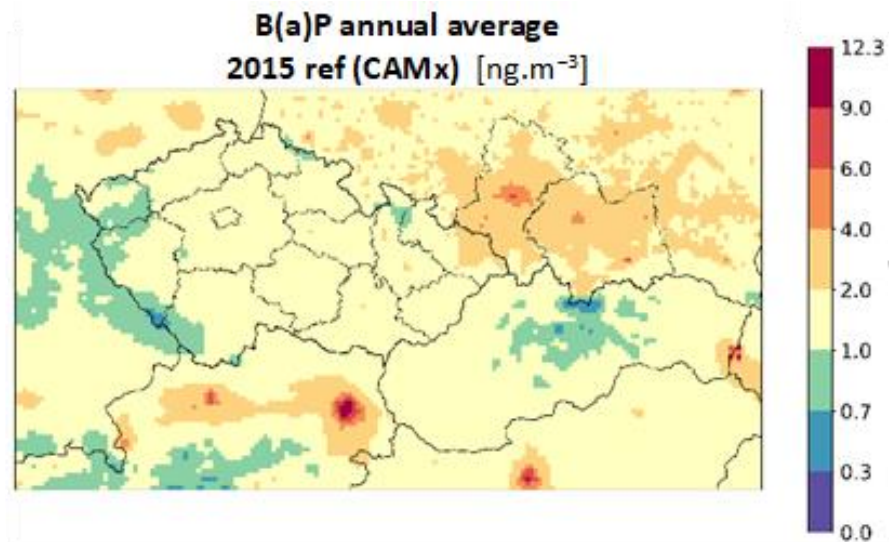
Relative change of PM<sub>2.5</sub> annual emissions  
 $100 * (2023 \text{ BAU} - 2015 \text{ ref}) / 2015 \text{ ref}$  [%]



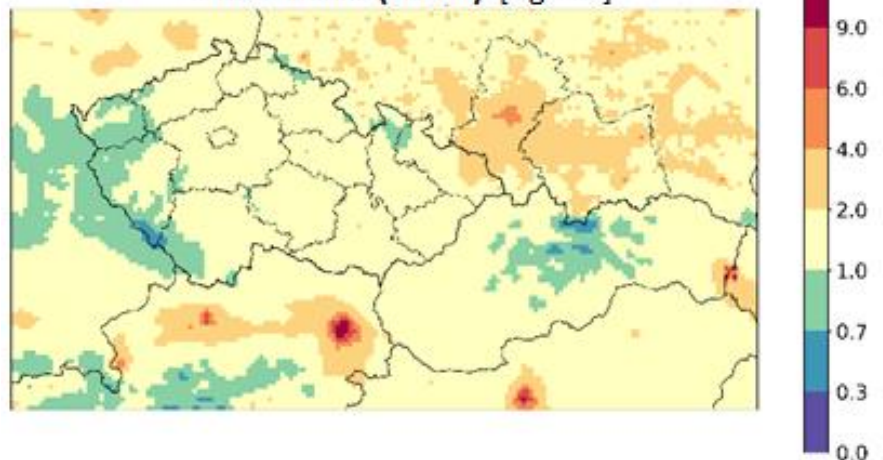
Relative change of PM<sub>2.5</sub> annual emissions  
 $100 * (2023 \text{ optimistic} - 2015 \text{ ref}) / 2015 \text{ ref}$  [%]



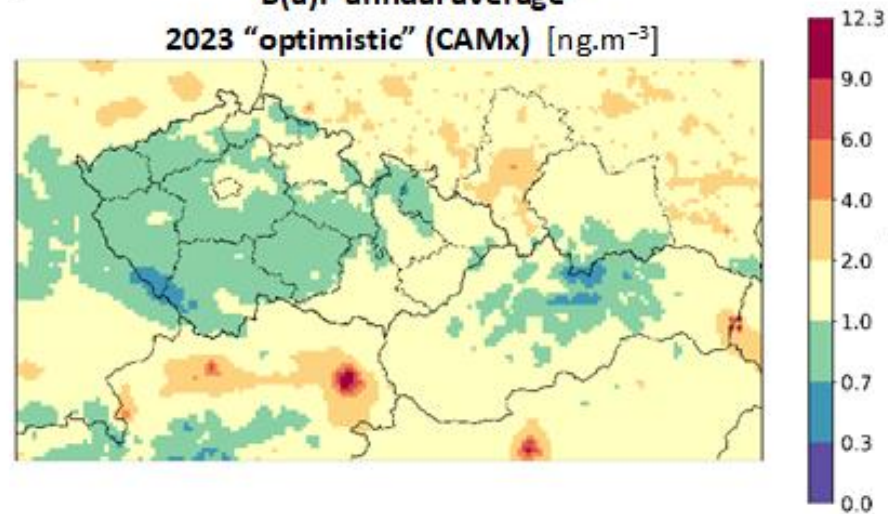
# Results B(a)P



**B(a)P annual average**  
2023 "BAU" (CAMx) [ng.m<sup>-3</sup>]

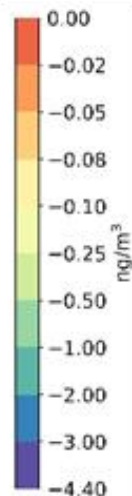
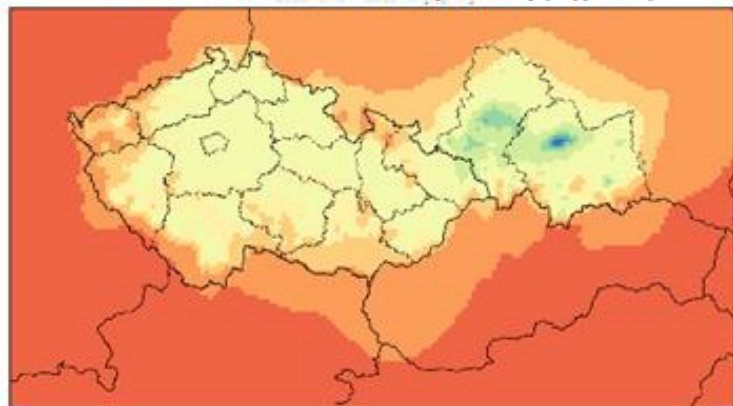


**B(a)P annual average**  
2023 "optimistic" (CAMx) [ng.m<sup>-3</sup>]

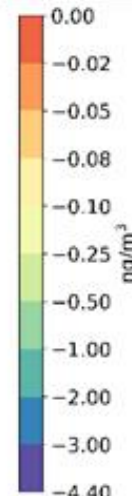
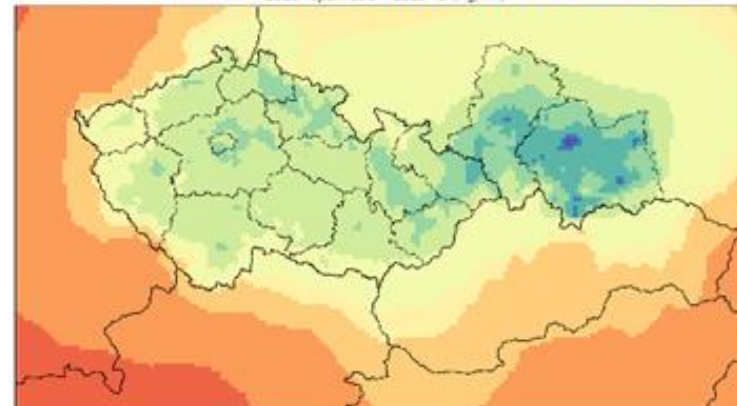


# Results B(a)P – changes CAMx

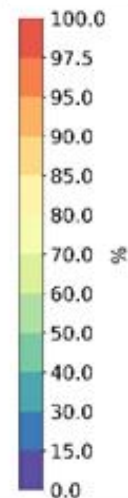
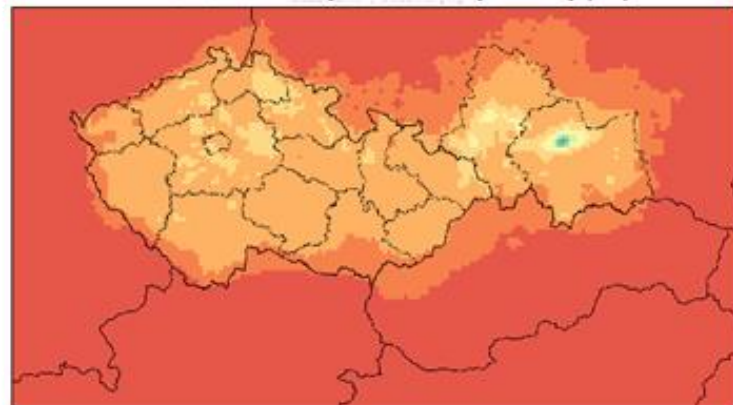
change of B(a)P annual average  
2023 "BAU" – 2015 ref (CAMx) [ $\text{ng}\cdot\text{m}^{-3}$ ]



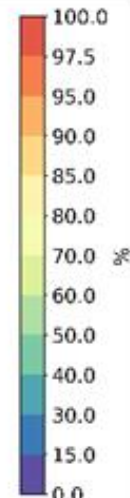
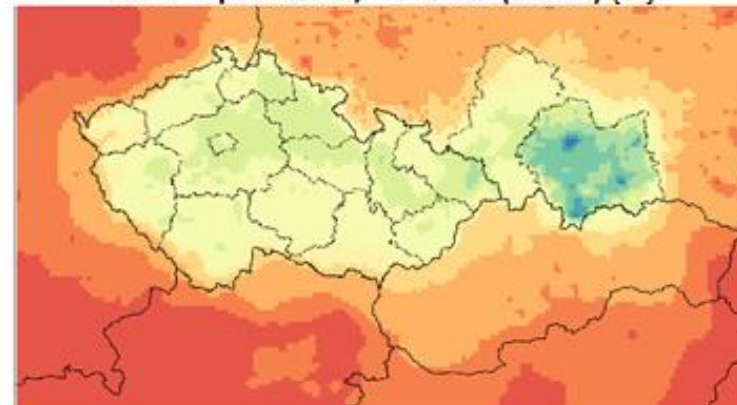
change of B(a)P annual average  
2023 "optimistic" – 2015 ref (CAMx) [ $\text{ng}\cdot\text{m}^{-3}$ ]



relative change of B(a)P annual average  
2023 "BAU" / 2015 ref (CAMx) [%]

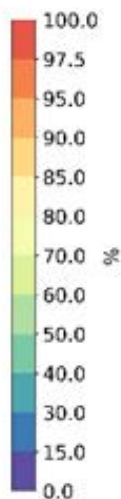
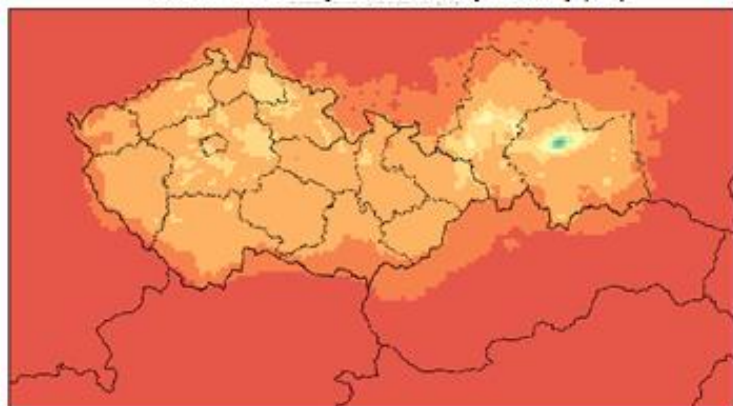


relative change of B(a)P annual average  
2023 "optimistic" / 2015 ref (CAMx) [%]

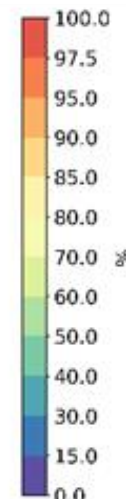
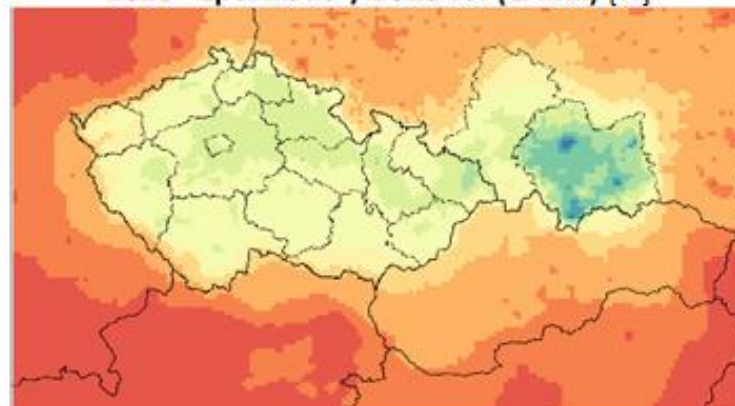


# Results B(a)P – changes CAMx vs CMAQ

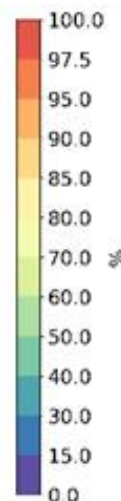
relative change of B(a)P annual average  
2023 "BAU" / 2015 ref (CAMx) [%]



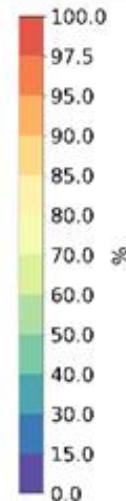
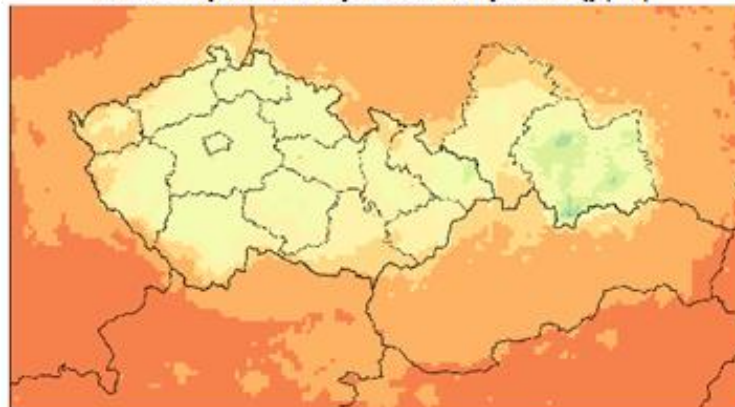
relative change of B(a)P annual average  
2023 "optimistic" / 2015 ref (CAMx) [%]



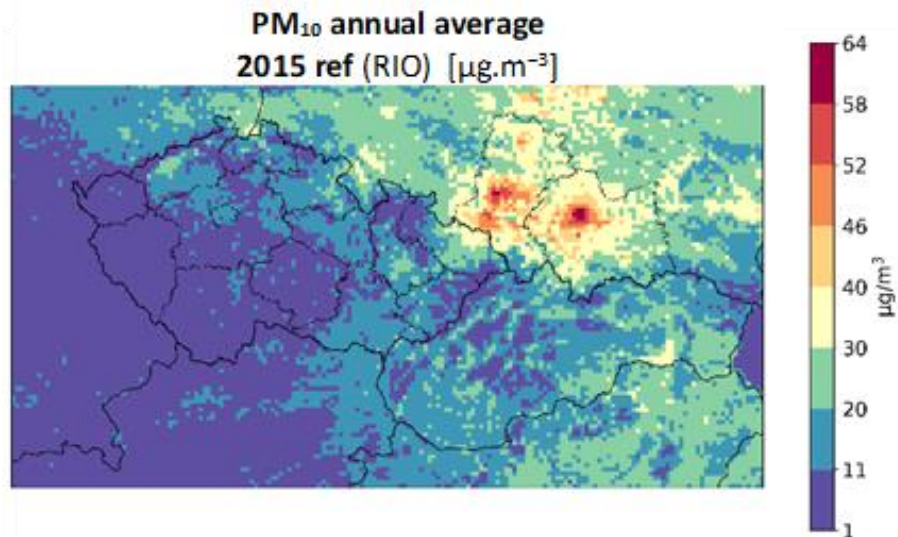
relative change of B(a)P annual average  
2023 "BAU" / 2015 ref (CMAQ) [%]



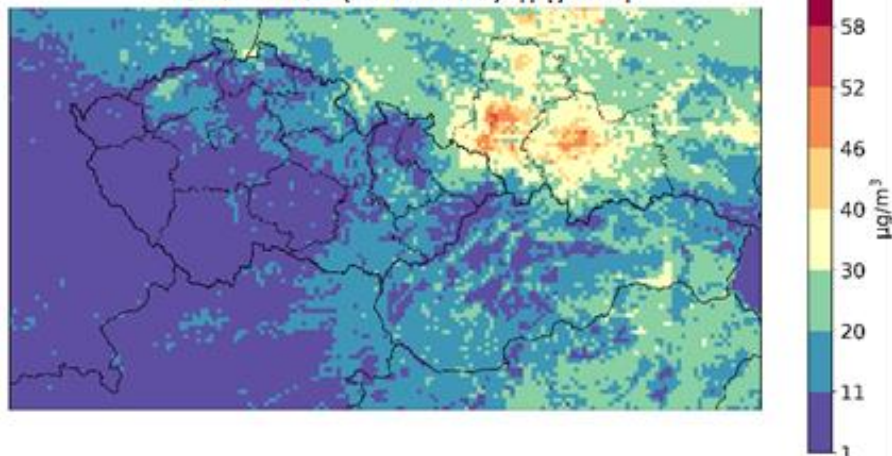
relative change of B(a)P annual average  
2023 "optimistic" / 2015 ref (CMAQ) [%]



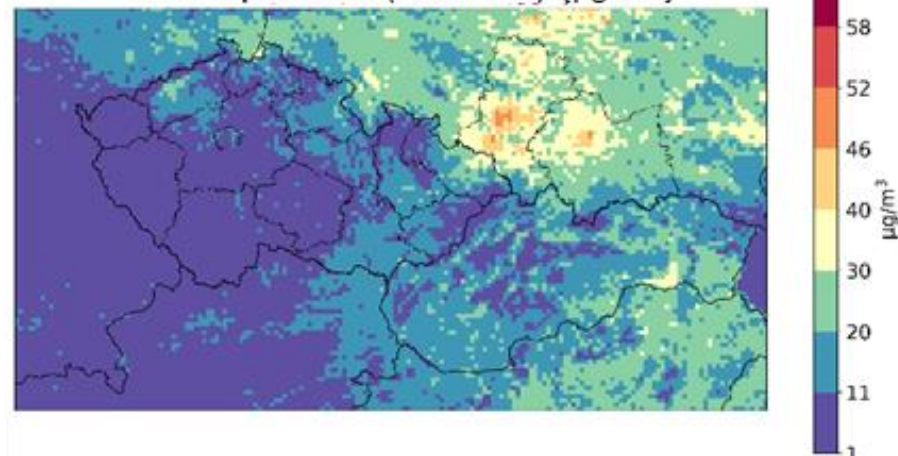
# Results PM<sub>10</sub> annual avg.



PM<sub>10</sub> annual average  
2023 "BAU" (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]

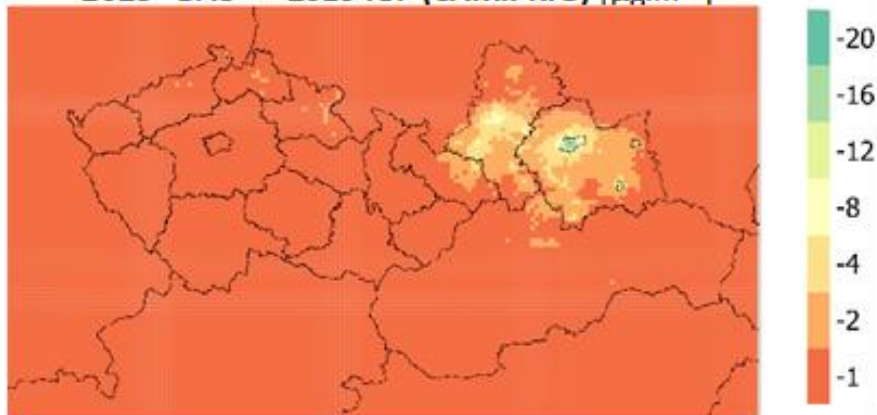


PM<sub>10</sub> annual average  
2023 "optimistic" (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]

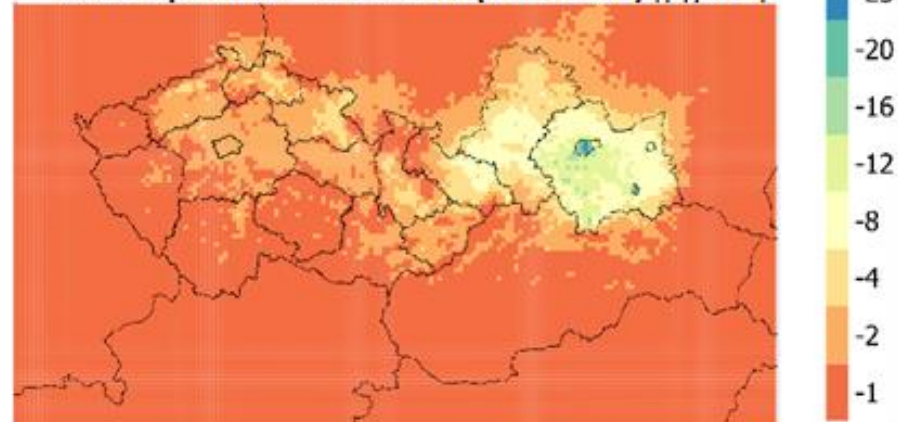


# Results PM<sub>10</sub> annual avg.

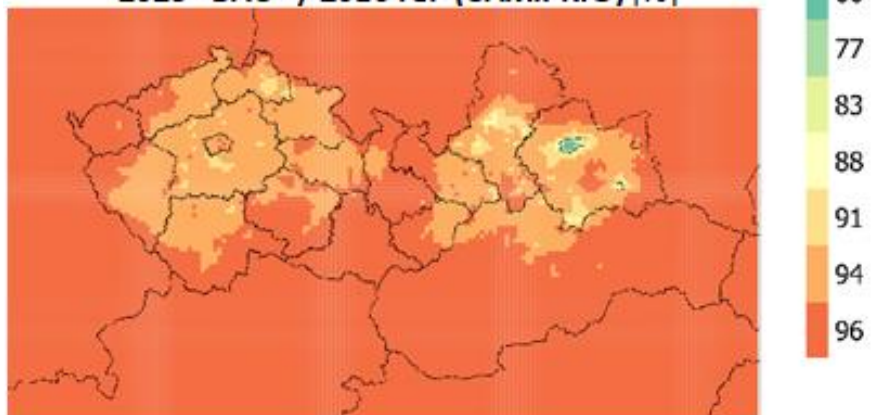
change of PM<sub>10</sub> annual average  
2023 "BAU" – 2015 ref (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]



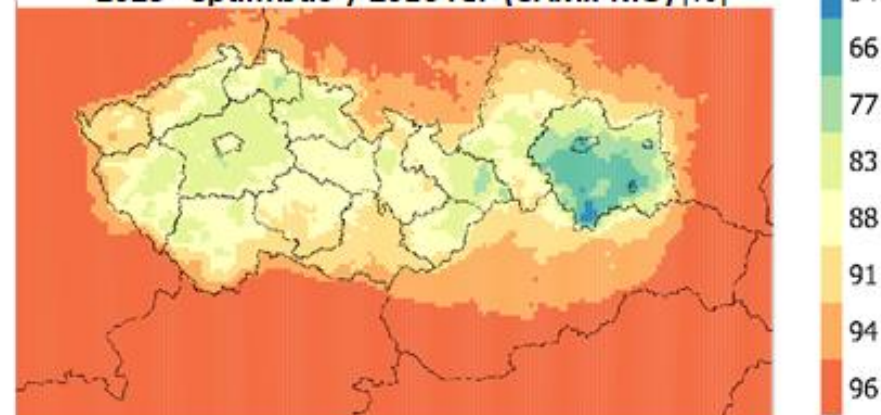
change of PM<sub>10</sub> annual average  
2023 "optimistic" – 2015 ref (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]



relative change of PM<sub>10</sub> annual average  
2023 "BAU" / 2015 ref (CAMx-RIO) [%]

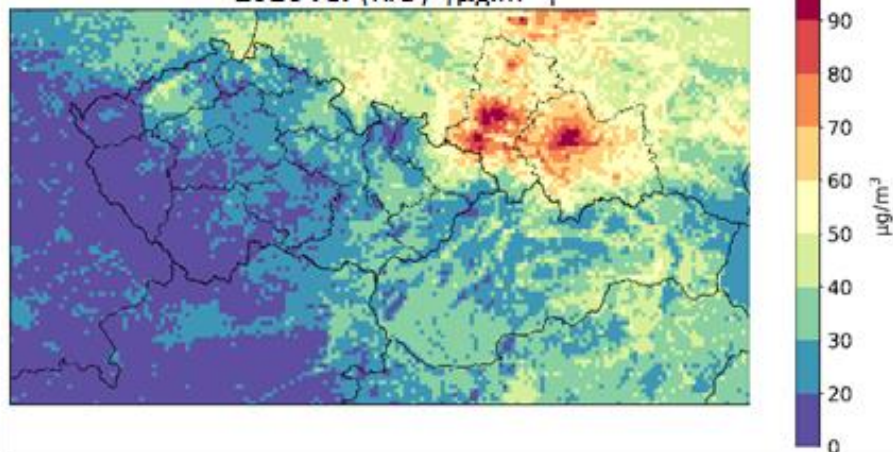


relative change of PM<sub>10</sub> annual average  
2023 "optimistic" / 2015 ref (CAMx-RIO) [%]

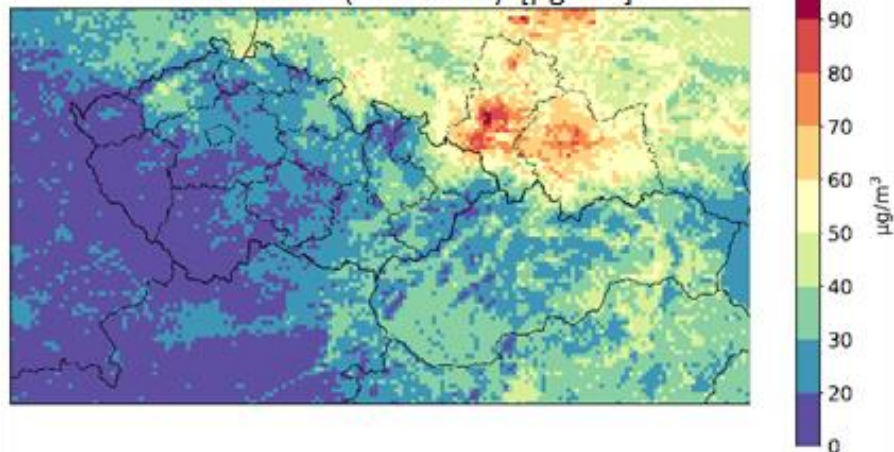


# Results PM<sub>10</sub> 36<sup>th</sup> highest daily avg.

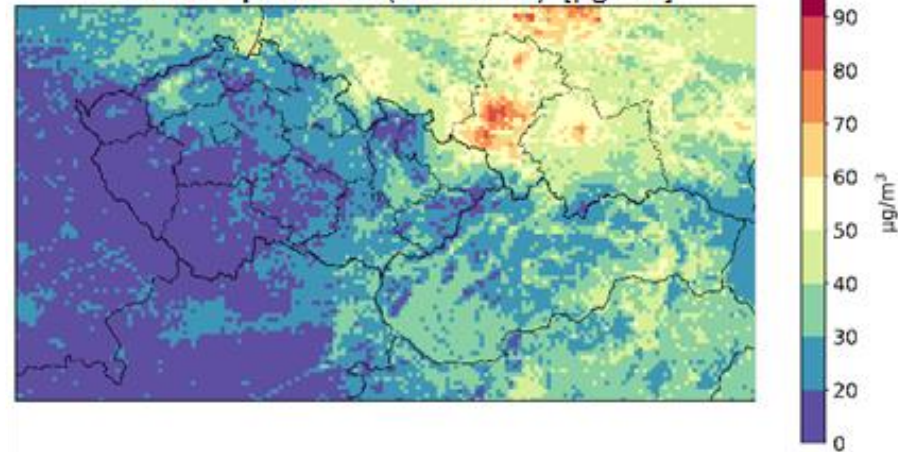
PM<sub>10</sub> 36<sup>th</sup> highest daily average  
2015 ref (RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]



PM<sub>10</sub> 36<sup>th</sup> highest daily average  
2023 "BAU" (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]

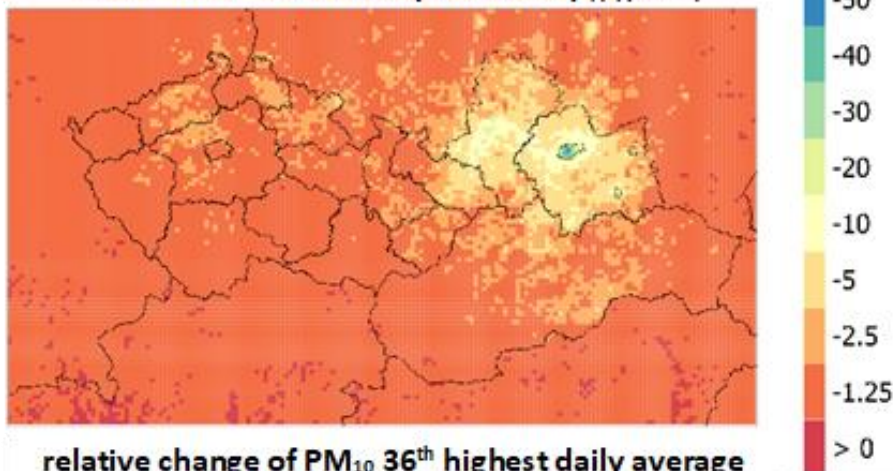


PM<sub>10</sub> 36<sup>th</sup> highest daily average  
2023 "optimistic" (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]

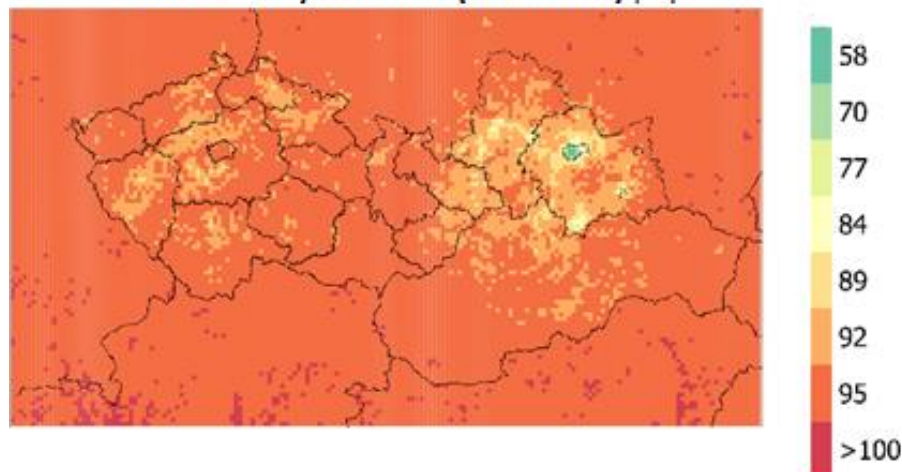


# Results PM<sub>10</sub> 36<sup>th</sup> highest daily avg.

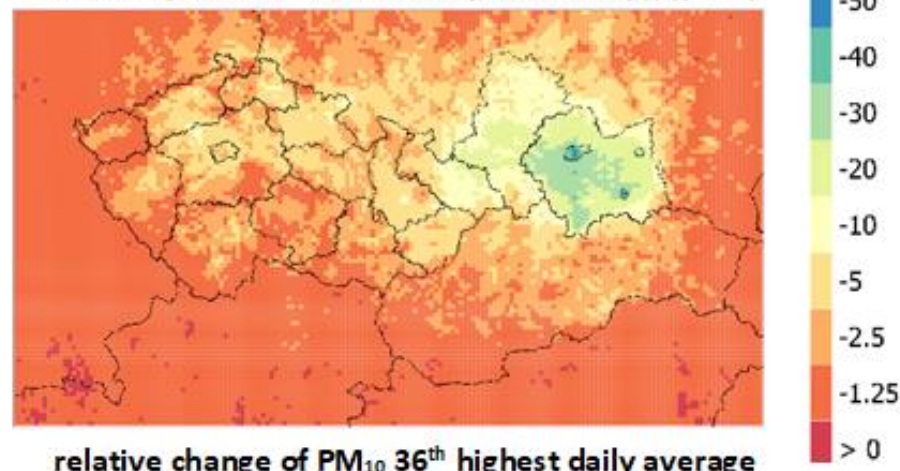
change of PM<sub>10</sub> 36<sup>th</sup> highest daily average  
2023 "BAU" – 2015 ref (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]



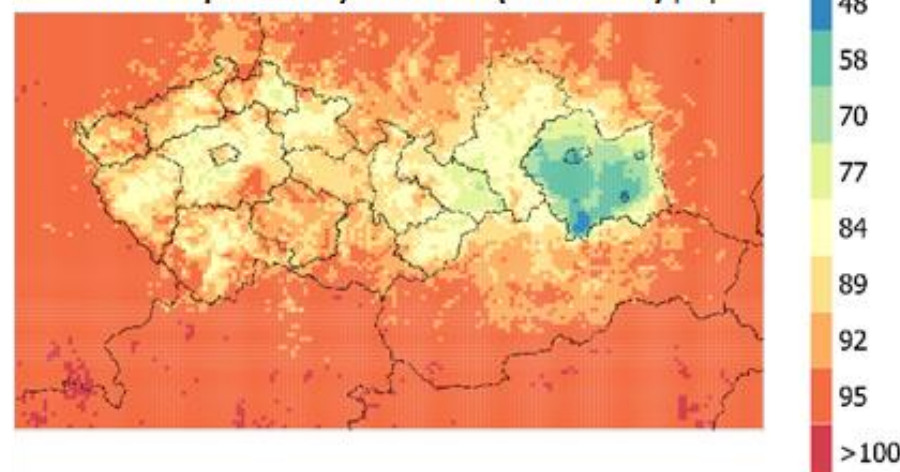
relative change of PM<sub>10</sub> 36<sup>th</sup> highest daily average  
2023 "BAU" / 2015 ref (CAMx-RIO) [%]



change of PM<sub>10</sub> 36<sup>th</sup> highest daily average  
2023 "optimistic" – 2015 ref (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]

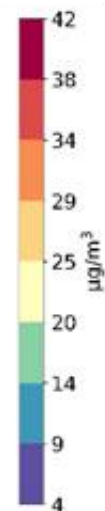
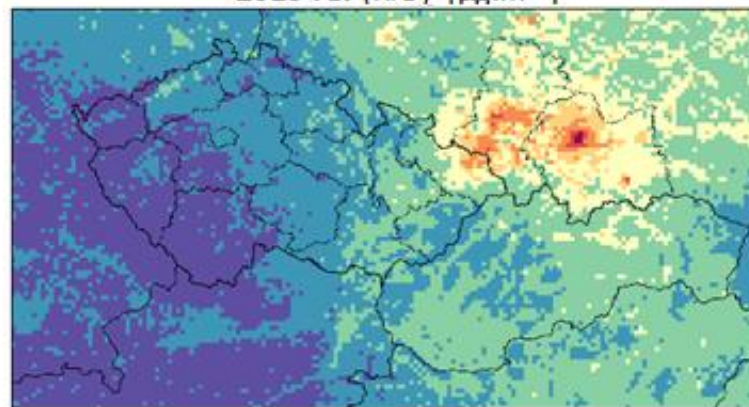


relative change of PM<sub>10</sub> 36<sup>th</sup> highest daily average  
2023 "optimistic" / 2015 ref (CAMx-RIO) [%]

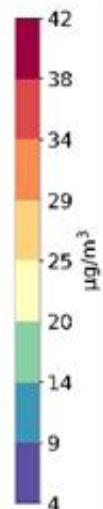
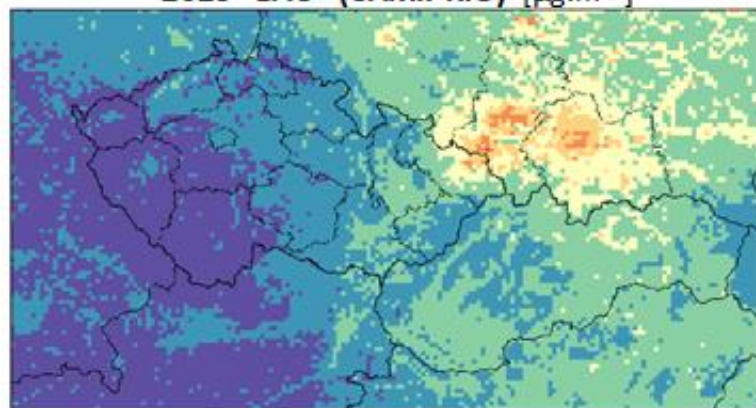


# Results $PM_{2.5}$

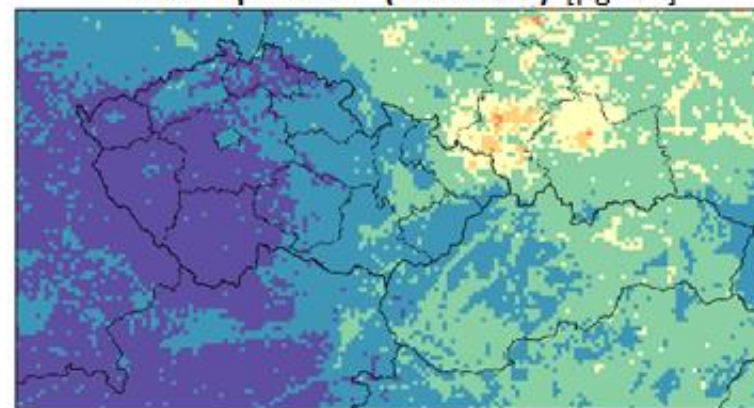
$PM_{2.5}$  annual average  
2015 ref (RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]



$PM_{2.5}$  annual average  
2023 "BAU" (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]

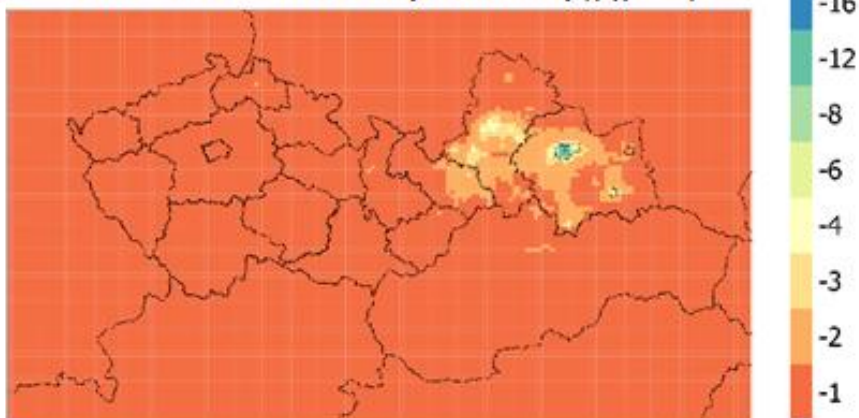


$PM_{2.5}$  annual average  
2023 "optimistic" (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]

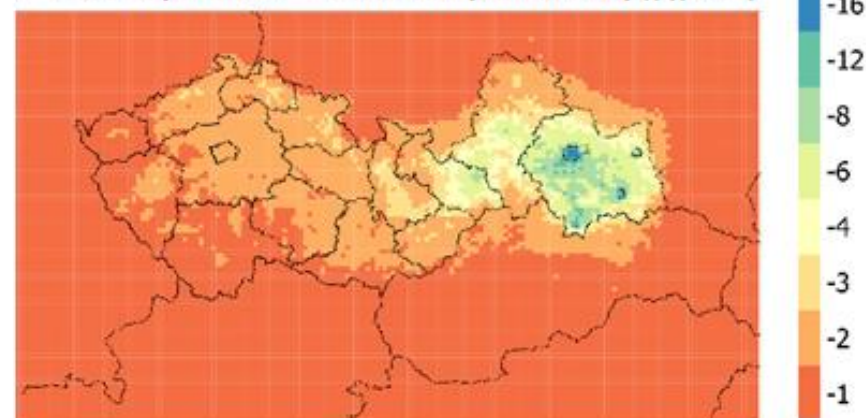


# Results PM<sub>2.5</sub>

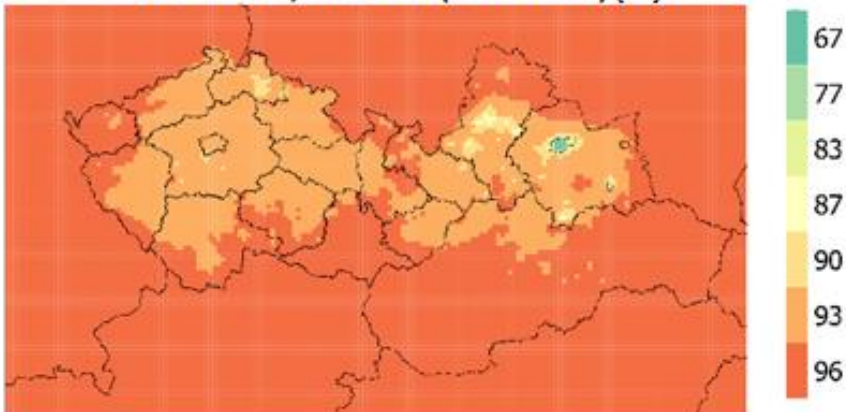
change of PM<sub>2.5</sub> annual average  
2023 "BAU" – 2015 ref (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]



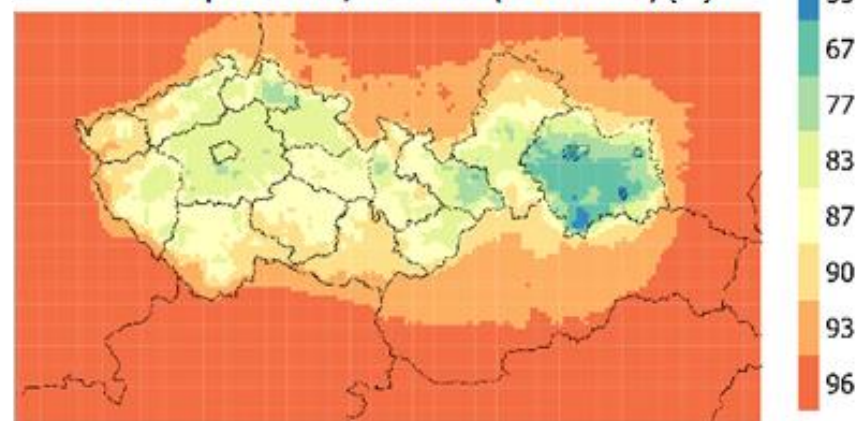
change of PM<sub>2.5</sub> annual average  
2023 "optimistic" – 2015 ref (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]



relative change of PM<sub>2.5</sub> annual average  
2023 "BAU" / 2015 ref (CAMx-RIO) [%]

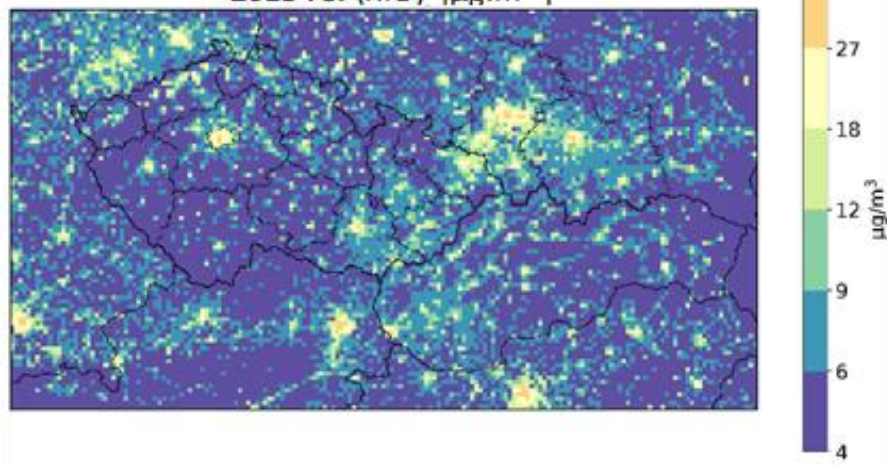


relative change of PM<sub>2.5</sub> annual average  
2023 "optimistic" / 2015 ref (CAMx-RIO) [%]

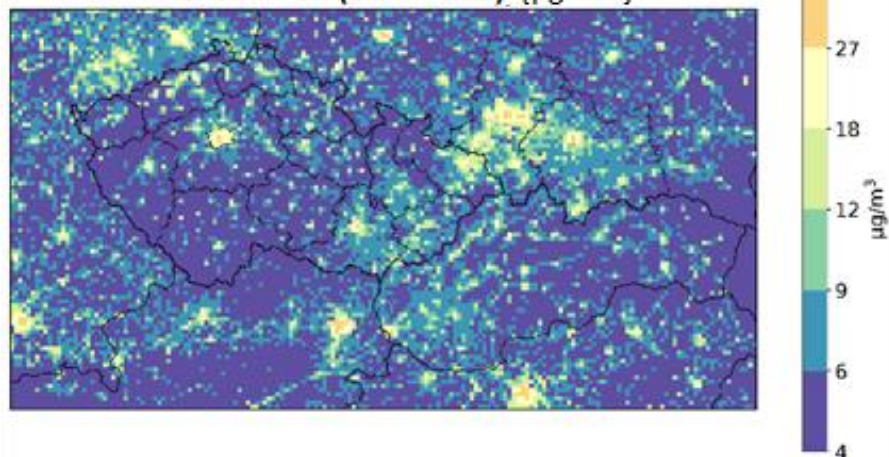


# Results NO<sub>2</sub>

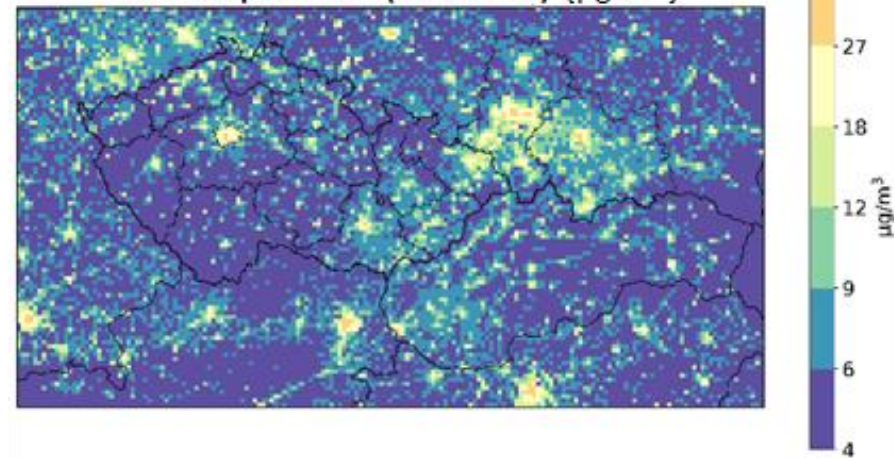
NO<sub>2</sub> annual average  
2015 ref (RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]



NO<sub>2</sub> annual average  
2023 "BAU" (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]

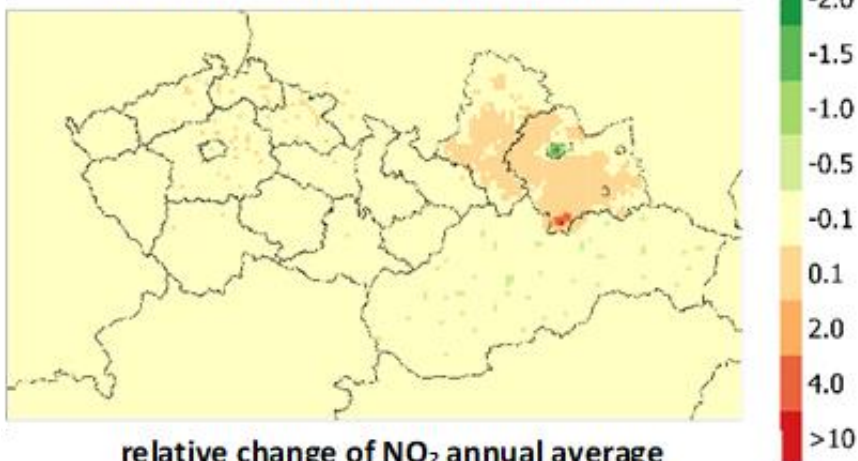


NO<sub>2</sub> annual average  
2023 "optimistic" (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]

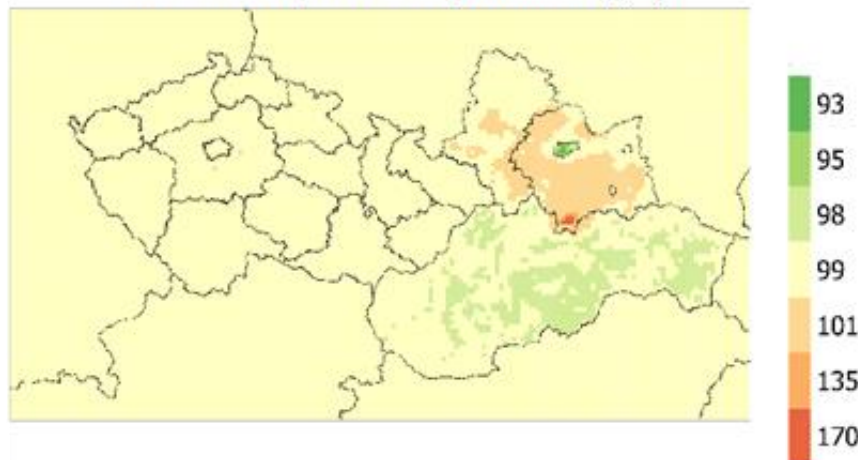


# Results NO<sub>2</sub>

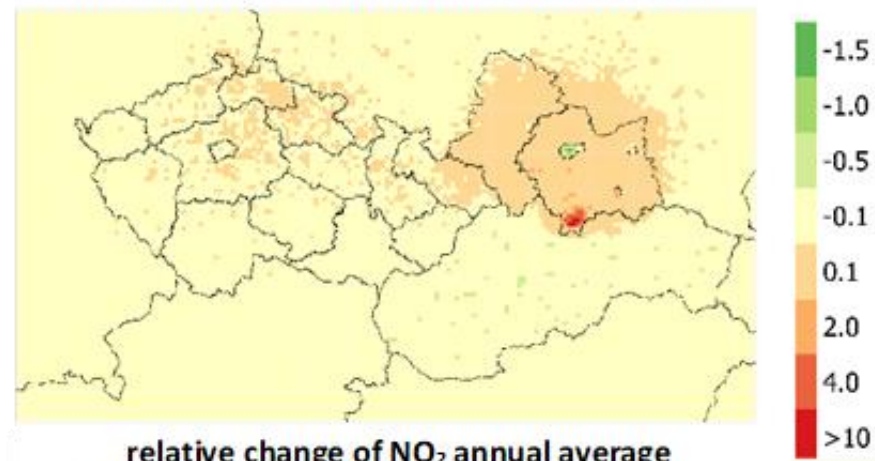
change of NO<sub>2</sub> annual average  
2023 "BAU" – 2015 ref (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]



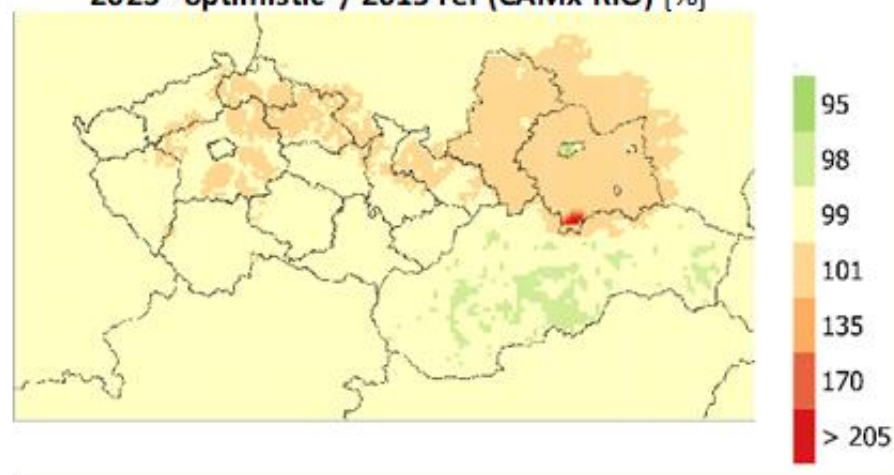
relative change of NO<sub>2</sub> annual average  
2023 "BAU" / 2015 ref (CAMx-RIO) [%]



change of NO<sub>2</sub> annual average  
2023 "optimistic" – 2015 ref (CAMx-RIO) [ $\mu\text{g}\cdot\text{m}^{-3}$ ]



relative change of NO<sub>2</sub> annual average  
2023 "optimistic" / 2015 ref (CAMx-RIO) [%]



# Summary - Małopolska

area > LV [%]

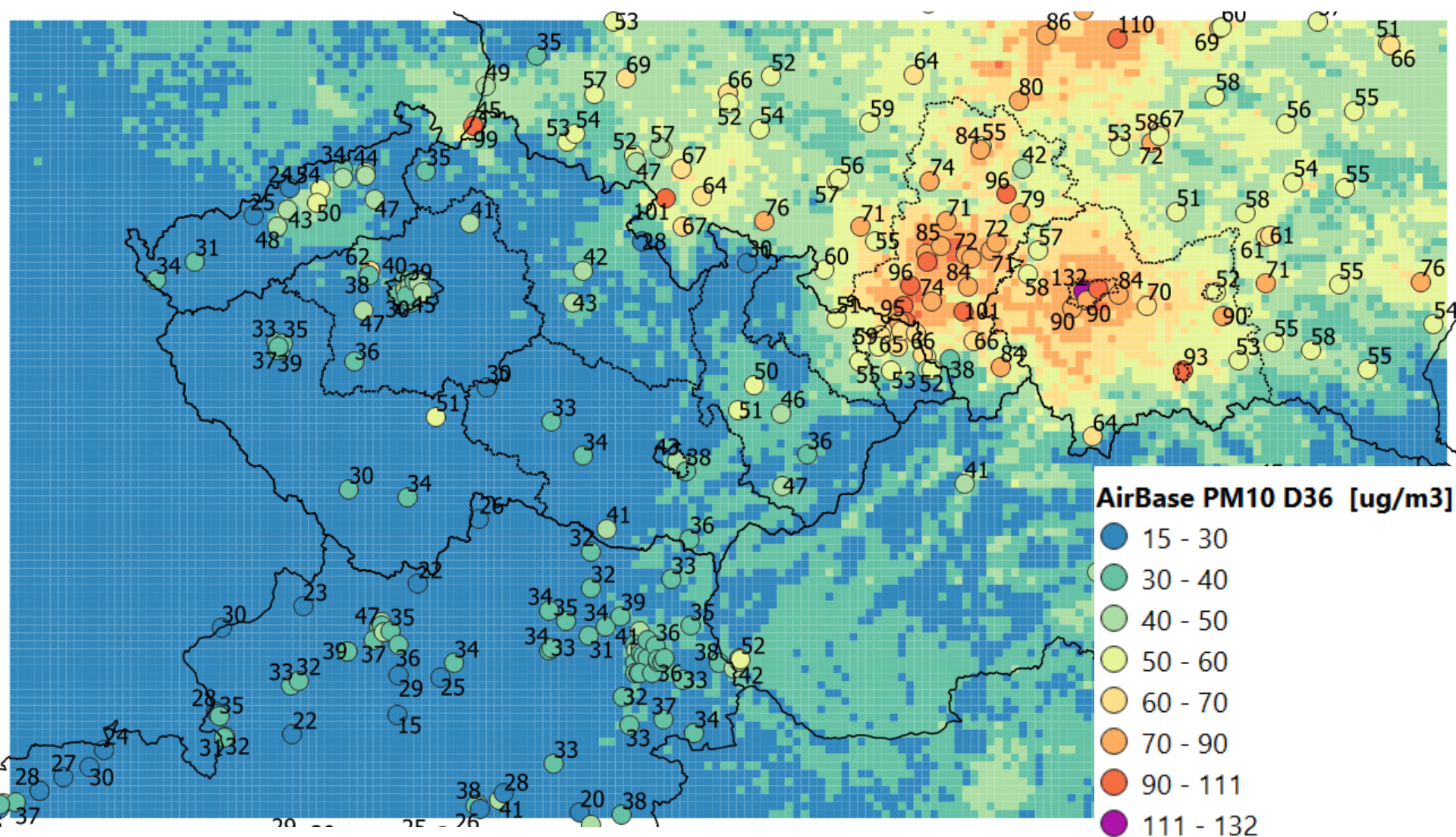
	RIO	BAU	opt	BAU avg – ref	opt. avg – ref
PM <sub>10</sub> annual avg.	20	12	2	-8	-18
PM <sub>10</sub> 36 <sup>th</sup> highest daily avg.	80	70	24	-11	-57
PM <sub>2.5</sub> annual avg.	86	76	29	-10	-56

relative change of B(a)P

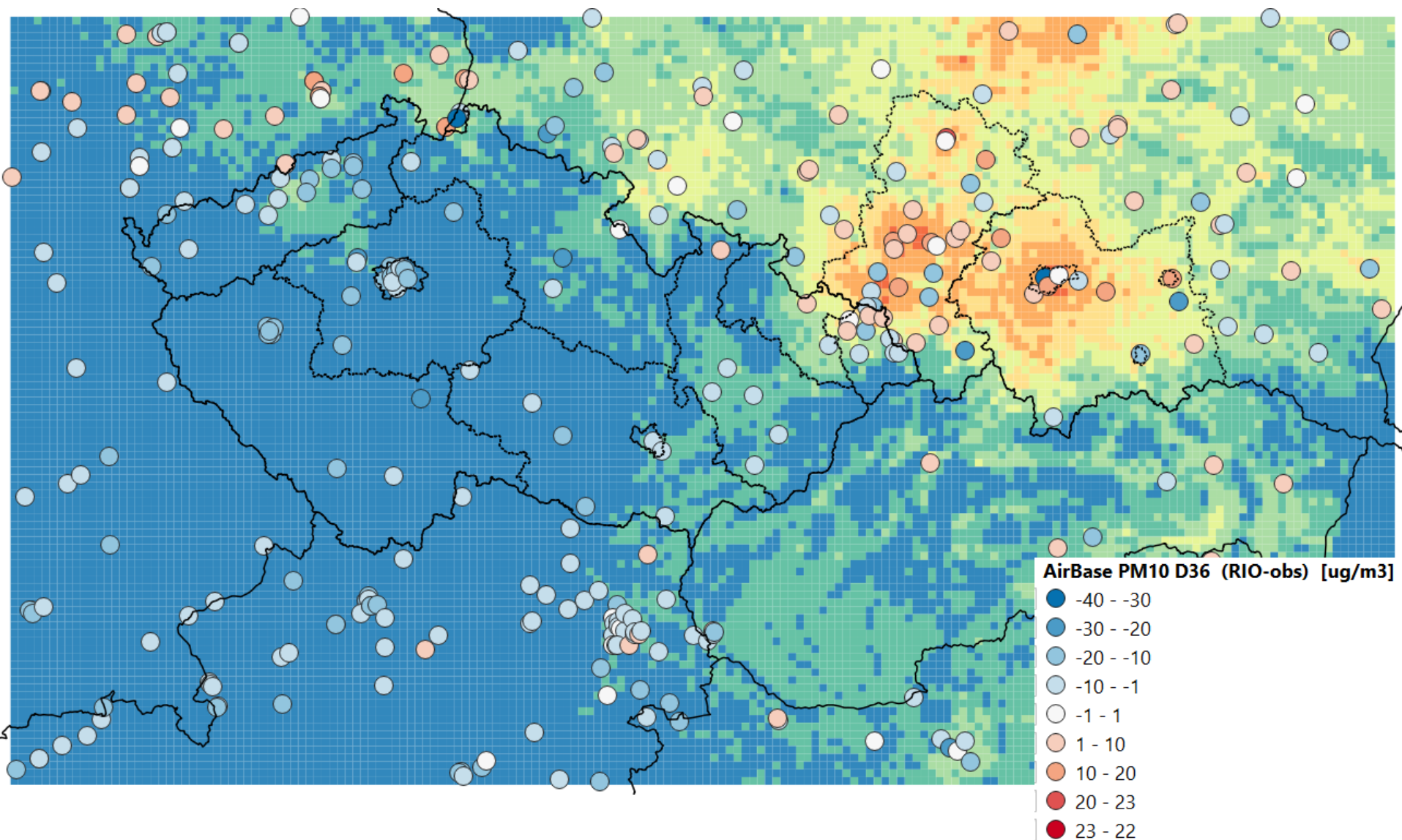
B(a)P	BAU/ref (%)		opt./ref (%)	
	CAMx	CMAQ	CAMx	CMAQ
10% perc.	96	92	72	83
median	93	87	55	73
90% perc.	88	84	44	66



# Project summary



# Project summary



# Summary - Silesia

area > LV [%]

	RIO	BAU	opt		BAU avg – ref		opt. avg – ref
PM <sub>10</sub> annual avg.	28	21	15		-6		-13
PM <sub>10</sub> 36 <sup>th</sup> highest daily avg.	85	80	67		-5		-18
PM <sub>2.5</sub> annual avg.	76	69	53		-7		-23

relative change of B(a)P

B(a)P	BAU/ref (%)		opt./ref (%)	
	CAMx	CMAQ	CAMx	CMAQ
10% perc.	95	95	84	88
median	92	92	75	84
90% perc.	87	87	69	80



# Summary - Czech Republic

area > LV [%]

	RIO	BAU	opt		BAU avg – ref		opt. avg – ref
PM <sub>10</sub> annual avg.	0,14	0,06	0,00		-0,08		-0,14
PM <sub>10</sub> 36 <sup>th</sup> highest daily avg.	1,54	1,01	0,53		-0,53		-1,01
PM <sub>2,5</sub> annual avg.	2,92	2,25	1,18		-0,67		-1,74

relative change of B(a)P

B(a)P	BAU/ref (%)		opt./ref (%)	
	CAMx	CMAQ	CAMx	CMAQ
10% perc.	95	93	81	85
median	92	90	73	79
90% perc.	90	88	67	74



# Summary - Slovakia

area > LV [%]

	RIO	BAU	opt		BAU avg – ref		opt. avg – ref
PM <sub>10</sub> annual avg.	0	0	0		0		0
PM <sub>10</sub> 36 <sup>th</sup> highest daily avg.	1,14	0,77	0,59		-0,36		-0,55
PM <sub>2.5</sub> annual avg.	5	4	3		-1		-3

relative change of B(a)P

B(a)P	BAU/ref (%)		opt./ref (%)	
	CAMx	CMAQ	CAMx	CMAQ
10% perc.	99	98	96	94
median	98	98	93	92
90% perc.	97	95	86	88



# Discussion

- Mostly only “officially existing sources” included (no biogenic PM emissions, wind resuspension, waste burning etc.), fugitive emissions to some extent only
  - changes can be in fact smaller



## Project summary

- Useful collaboration in emission exchange
- Experience with real possibilities to harmonize residential heating emissions
- Need of
  - more reliable emission inventory for B(a)P
  - model for B(a)P and/or modelling guidance



**Thank you!**

