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Improved understanding of source contributions to urban $PM_{2.5}$ in Europe and EECCA with GAINS

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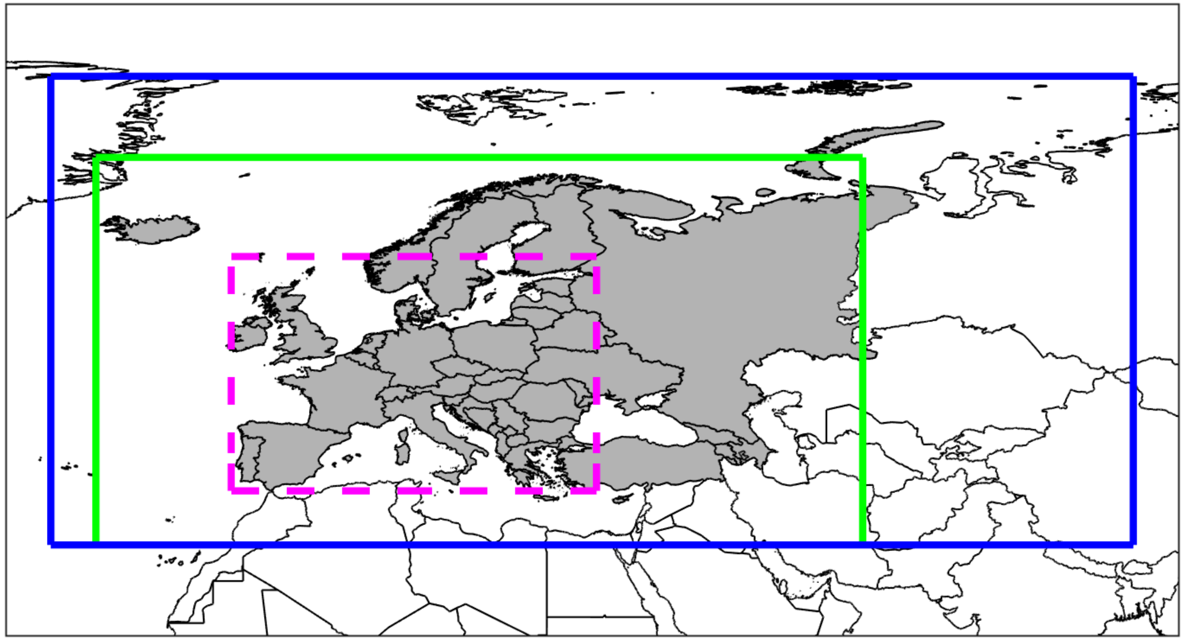
Domains in GAINS



45 GAINS-Europe emission regions

“28km” impact domain

“7km” downscaling

New EMEP domain
covering all EECCA countries

⇒ New transfer coefficients needed
(MSC-W end of 2021)

⇒ New downscaling needed (uEMEP)

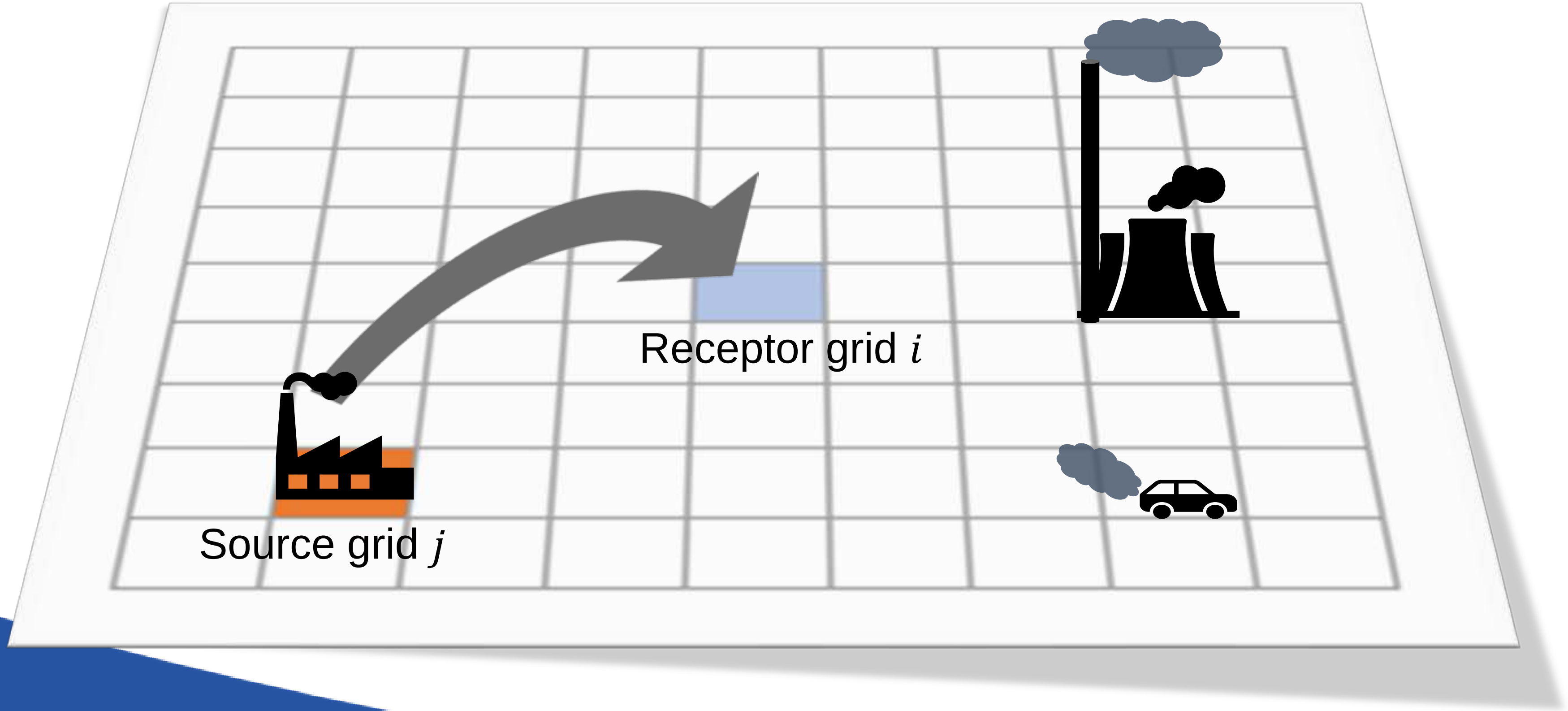
New transfer coefficients in GAINS

- Extended EMEP domain
- Resolution: 0.3°x0.2°
- Base case: 2030 Baseline scenario
- Reduction simulations for 50 land regions (incl split of Turkmenistan, Uzbekistan, Tajikistan) and 10 sea regions (5 seas, inside/outside 12nm)
- 5 met years (figures here use 2019 met!)
- 5 source pollutants (PPM, SO_2, NOx, NH_3, VOC)
  - Separate reduction for soil NOx – not yet implemented in GAINS
  - No separate treatment of dispersion of condensable PM (yet)
- Endpoints:
  - concentrations of $PM_{2.5}$, O_3 (SOMO35, AOT), NO_2
  - Health impacts from $PM_{2.5}$, O_3
  - Deposition -> ecosystem impacts (using updated CLs, yet to be implemented)

Extension with grid-to-grid tracking of PPM

- EMEP CTM can track PPM contributions grid-to-grid (0.1°)
- 4 different vertical emission “layers” (low-level 1&2, industry, power)
- monthly results allow for sector-specific time patterns

Sector specific transfer coefficients

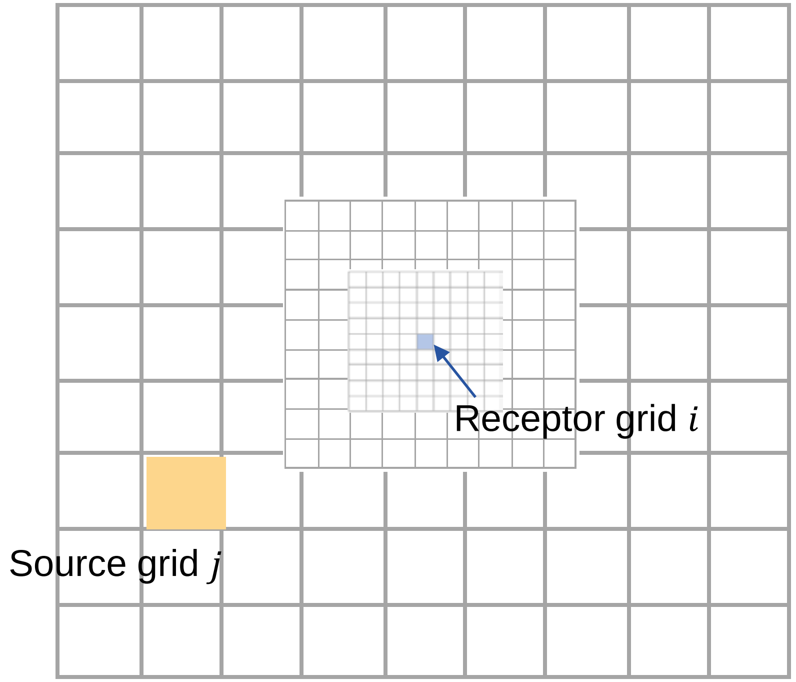


Extension with grid-to-grid tracking of PPM

- EMEP CTM can track PPM contributions grid-to-grid (0.1°)
- 4 different vertical emission “layers” (low-level 1&2, industry, power)
- monthly results allow for sector-specific time patterns
- five nested resolutions for source grids: 0.1° / 0.2° / 0.5° / 1° (/ 2°)

20 grid cells in each direction => Complete domain coverage

Sector specific transfer coefficients (0.1°)



5 met year average has been calculated but so far only 2019 implemented

Combination: Sector specific transfer coefficients

- GAINS transfer coefficients for secondary aerosols: linear approximation of EMEP CTM

  From source regions r, source pollutant p, to PM2.5 in receptor grid cell i:

$$T_{r,p,i} = \frac{[PM_{2.5}]_{i,base} - [PM_{2.5}]_{i,red}}{0.15 \cdot Emis_{r,p}}$$

- Grid to grid tracking ("local fraction") of PPM with EMEP CTM at 0.1^{o}, monthly results

  => sectoral transfer coefficients for PPM:

$$T_{r,s,i} = \frac{1}{12} \cdot \sum_{t=1}^{12} \sum_{j} D(r,s,l(s),j) \cdot \tau(s,j,t) \cdot G(j,i,l,t)$$

r... source region, s... source sector, i... receptor grid cell (0.1^{0}), j... emission grid cell (0.1^{0}), l...vertical emission layer, t...month

$D(r,s,l,j)$ ... spatial emission distribution pattern

$\tau(s,j,t)$ ... temporal (monthly) emission share

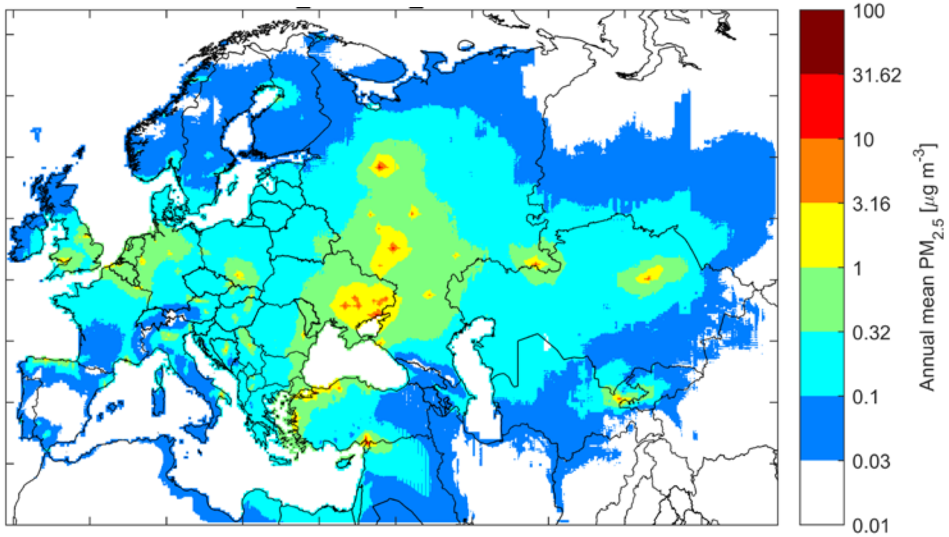
$G(j,i,l,t)$... grid-to-grid transfer coefficient from j to i in month t for emission layer l

- So that $[\mathrm{PM}_{2.5}]_{i,scen} = \delta_i + \sum_s \sum_r \sum_p Emis_{r,s,p,scen} \cdot T_{r,p,s,i}$

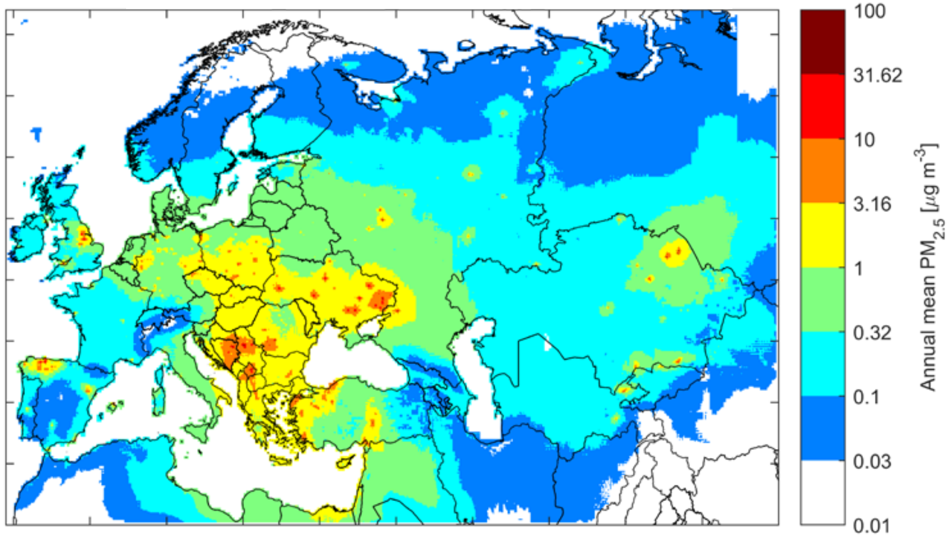
  (applying relative sectoral contributions also to SO_2 and NOx transfer coefficients)

Ambient $PM_{2.5}$: Contributions from sectors (2015)

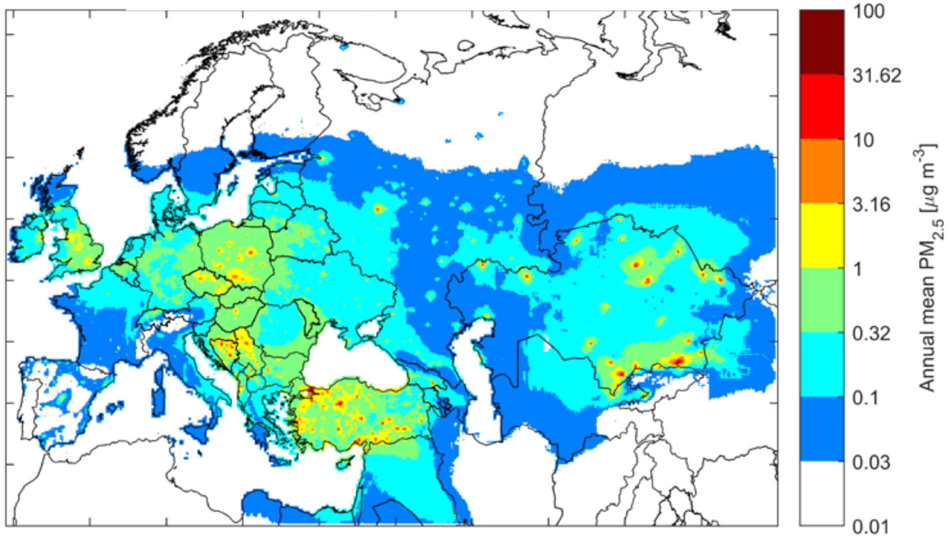
Iron & steel industry



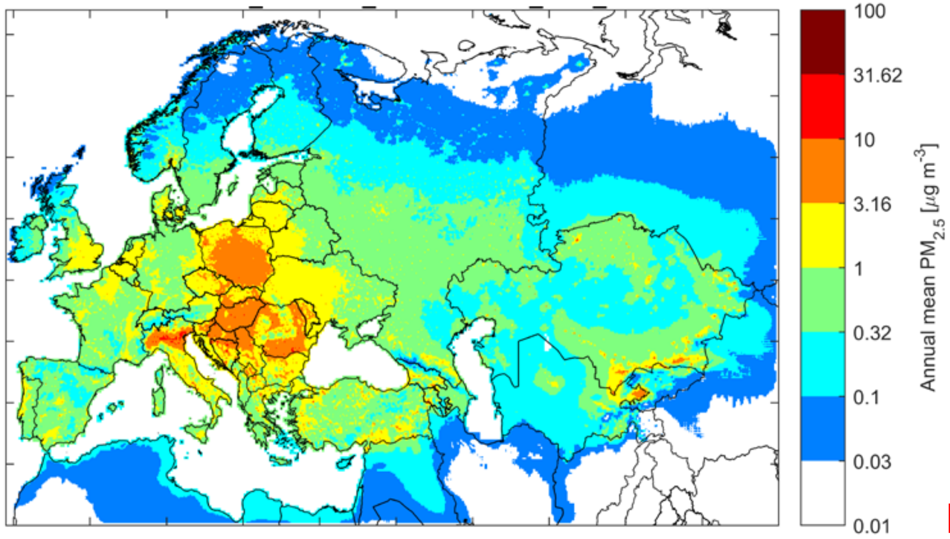
Coal power plants



Heating: urban



Heating: rural



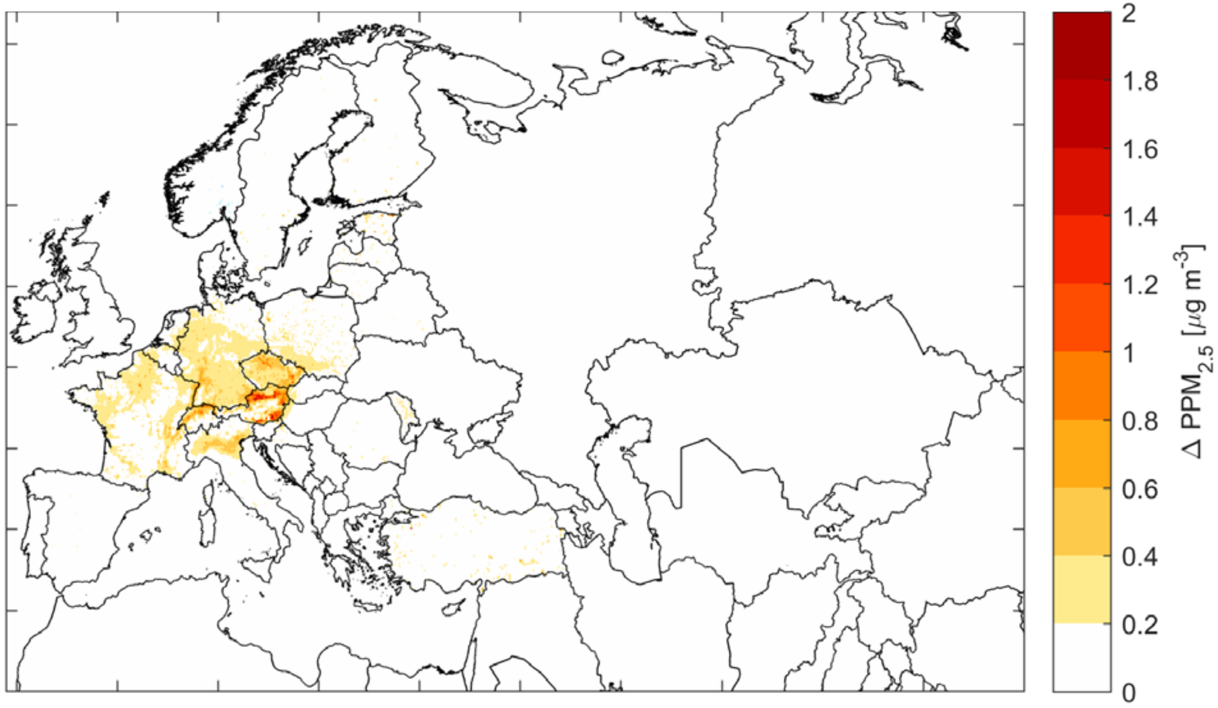
Done for ~40 sectors.

Preliminary results!

BTW... What about condensables?

Impact of including ‘consistent – *typical*’ emission factors including condensable PM, compared to the current GAINS emission factor datasets:

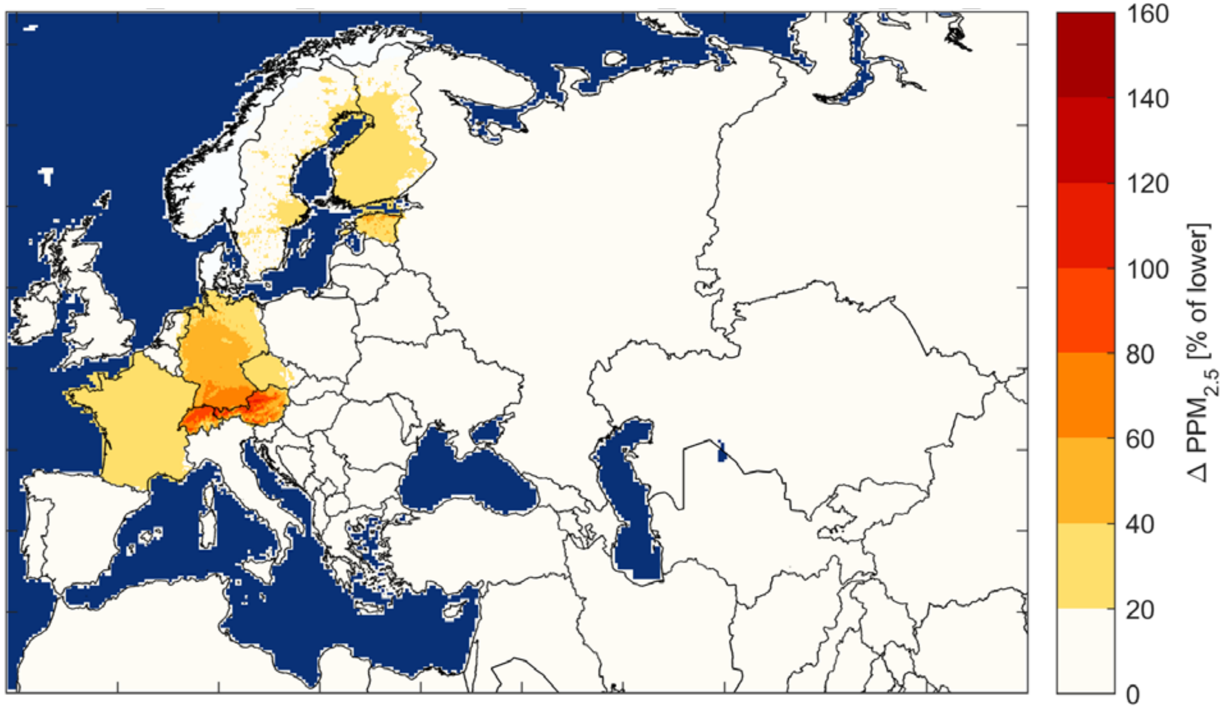
$PPM_{2.5}$ from rural residential heating (2015):
Absolute change



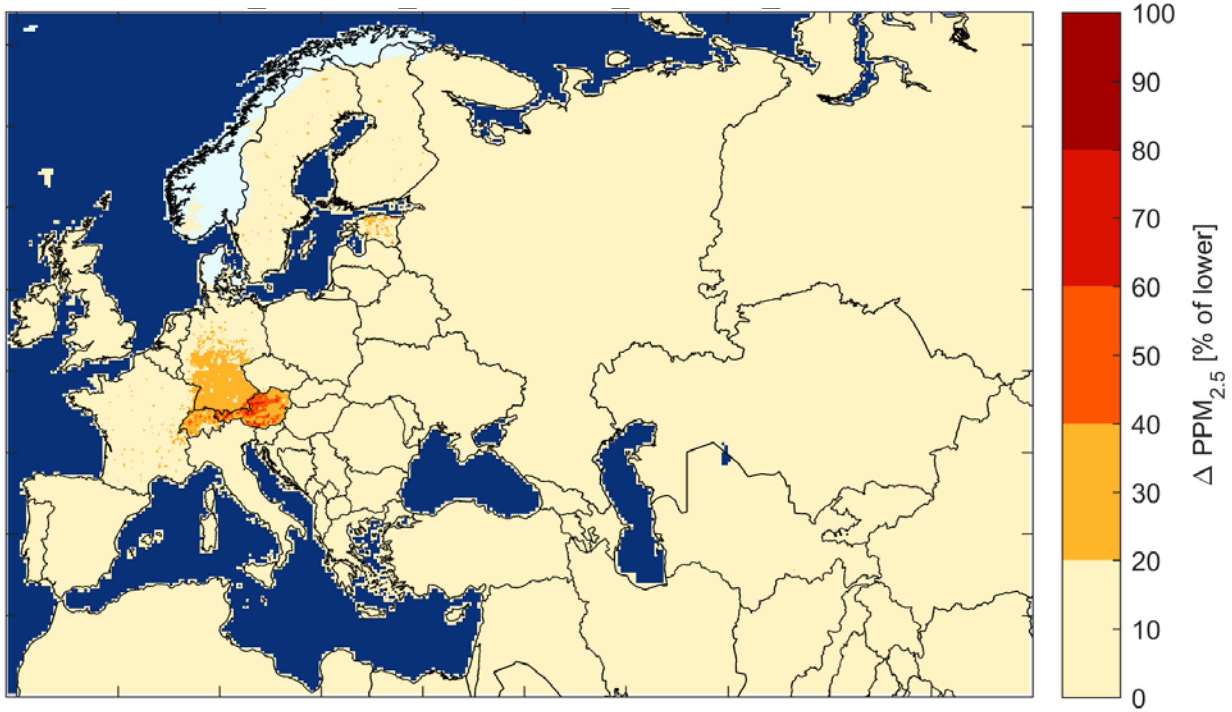
BTW... What about condensables?

Impact of including ‘consistent – *typical*’ emission factors including condensable PM, compared to the current GAINS emission factor datasets:

$PPM_{2.5}$ from rural residential heating (2015): Relative change

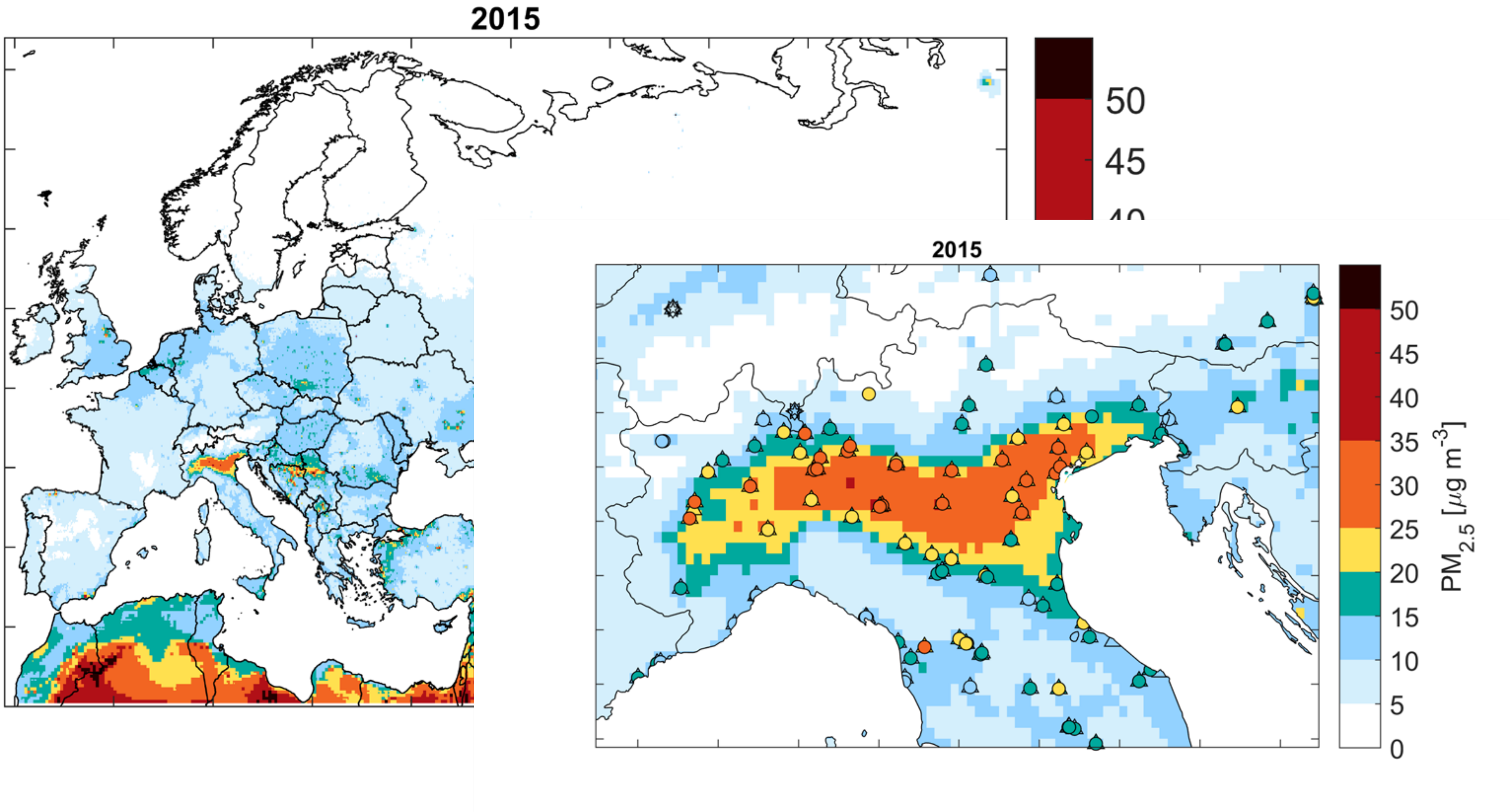


Effect on total $PPM_{2.5}$ (2015)



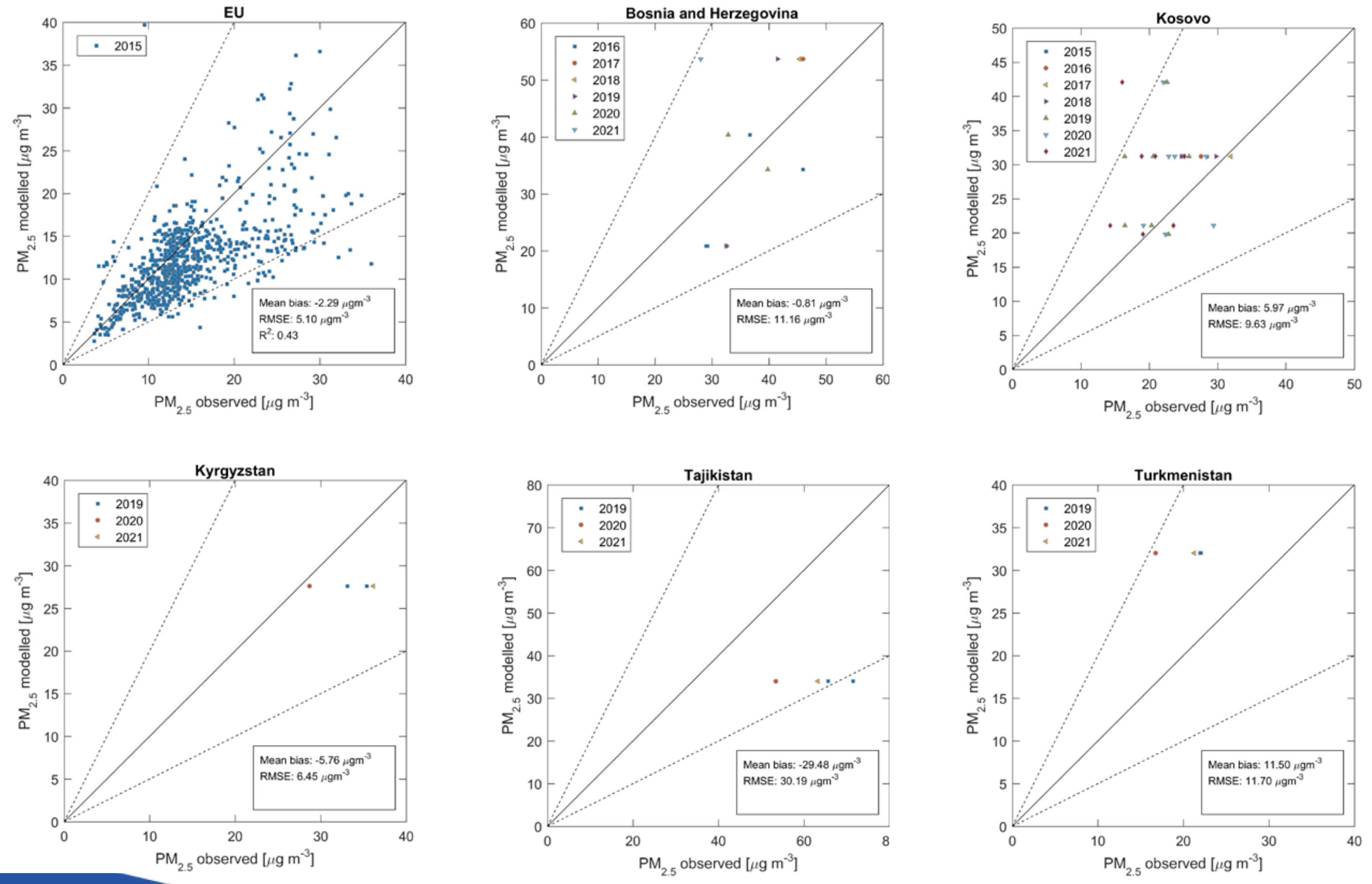
Considerable increase in PPM in a few countries, mostly AT, CH, DE, FR. Otherwise GAINS current emission factors are already similar to the ‘consistent – typical’ set.

Ambient $PM_{2.5}$ concentrations



Preliminary results!

Ambient $PM_{2.5}$ concentrations – validation

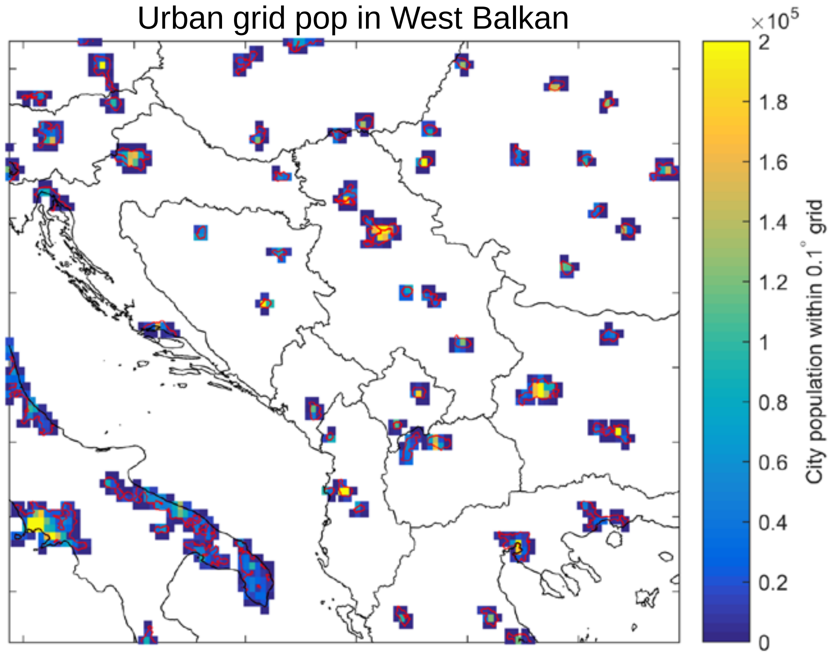


Non-EU: Not many stations available… (WHO DB 2022, AirBase, US Embassies)

Preliminary results!

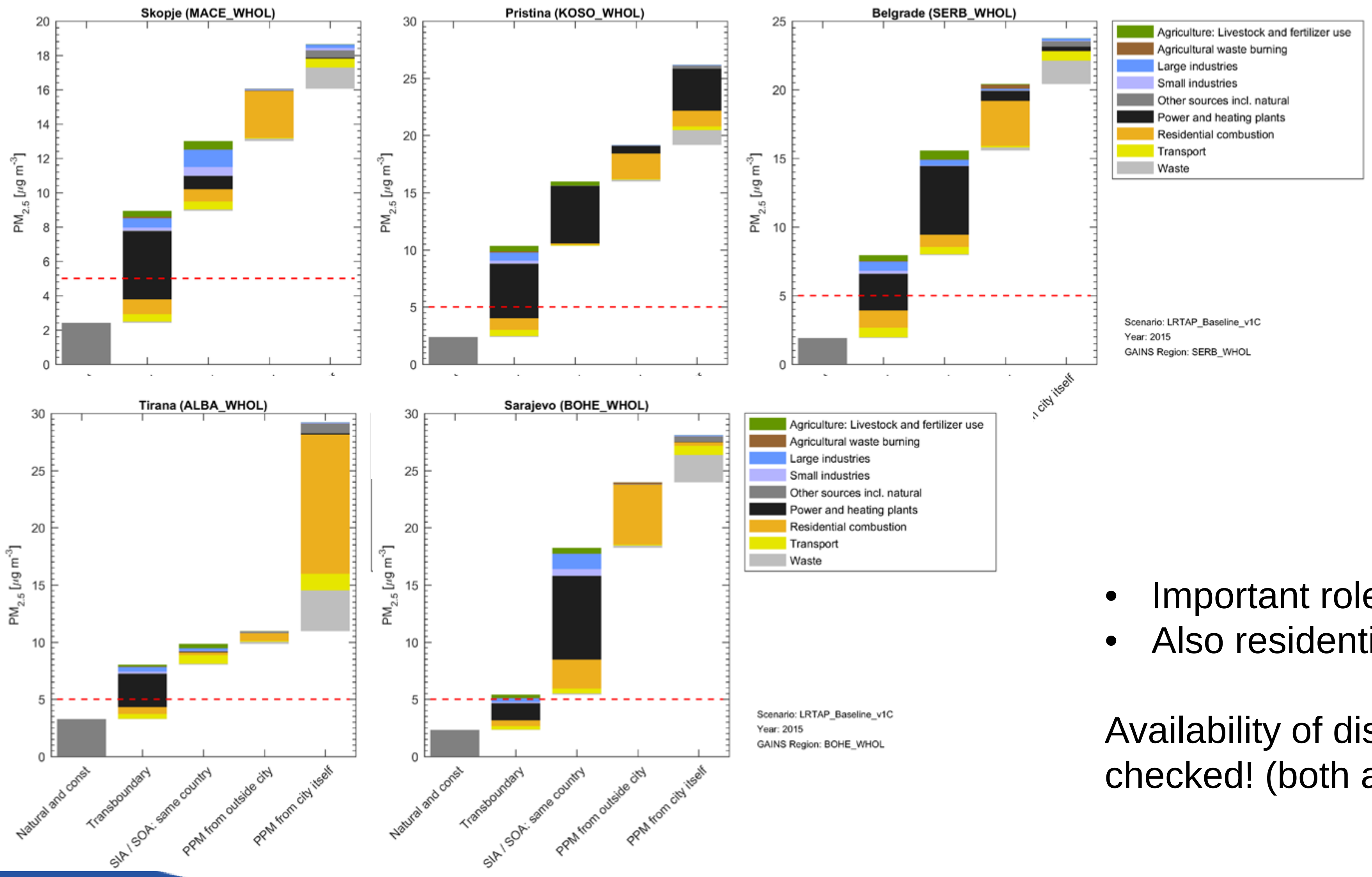
Contributions to $PM_{2.5}$ in cities: Approach

- Application of the grid-to-grid PPM transfer coefficients:
  - For each city, split sectoral PPM transfer coefficients into contributions from the same city and outside
- City definition currently hybrid: GRUMP urban polygons + 250m grid population (GHSL R2015A) with population density threshold (10/ha), filtered for total pop in polygon



- 300 cities > 200,000 inhabitants in the extended GAINS-Europe domain (175 non-EU)
- Other definitions of city extents can (and should) be tested
- So far: “urban background” (0.1°) - downscaling planned based on uEMEP

Source contributions to cities: West Balkan (2015)

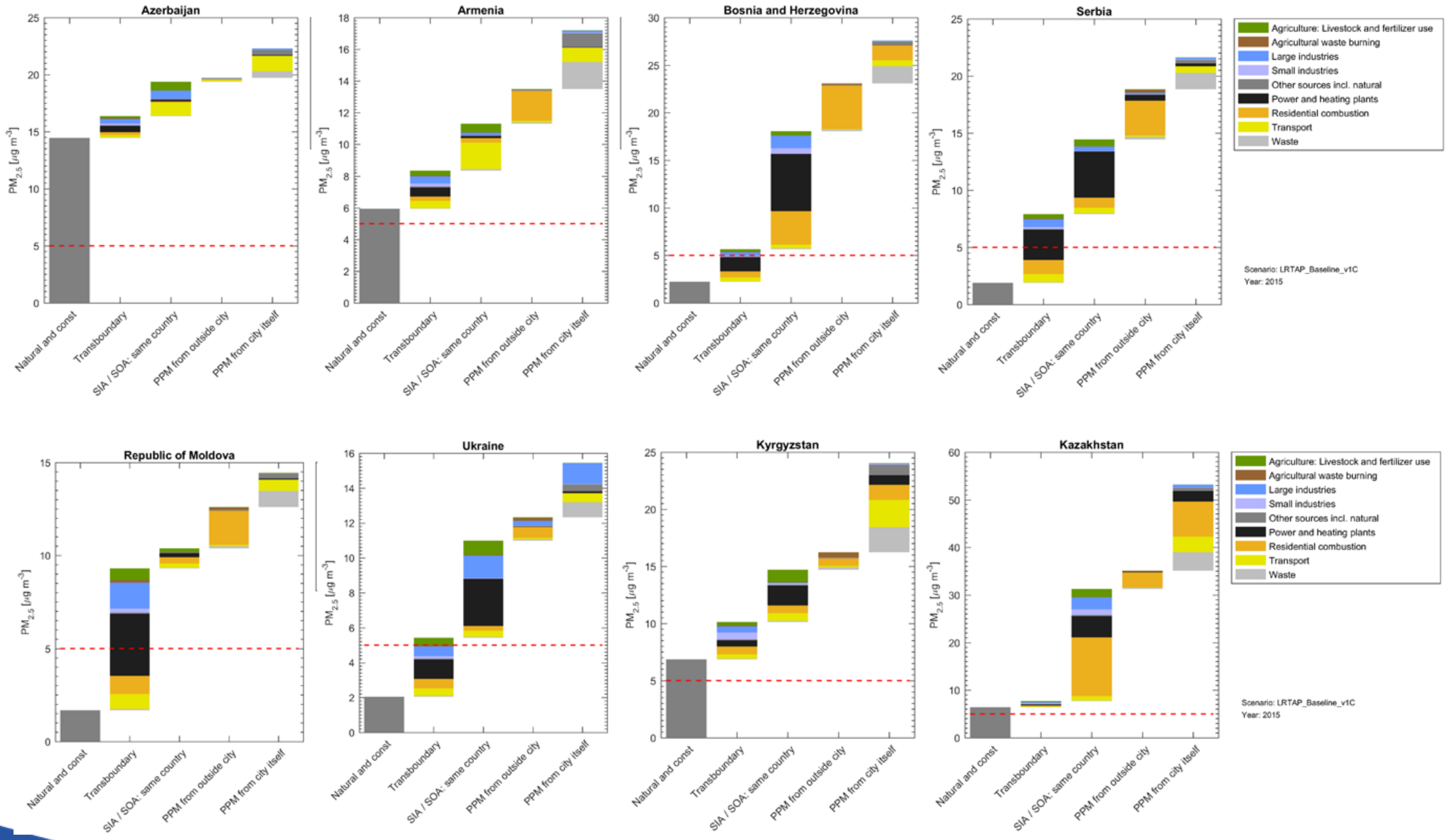


- Important role of power/heating plants
- Also residential sector

Availability of district heating needs to be checked! (both at national and city level)

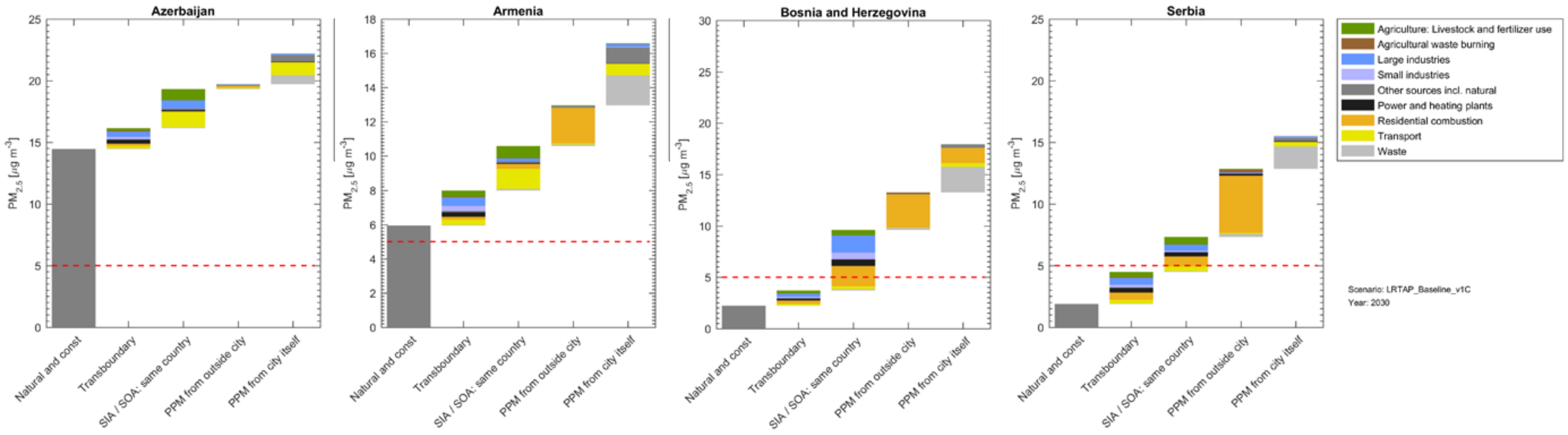
Preliminary results!

Country means: 2015



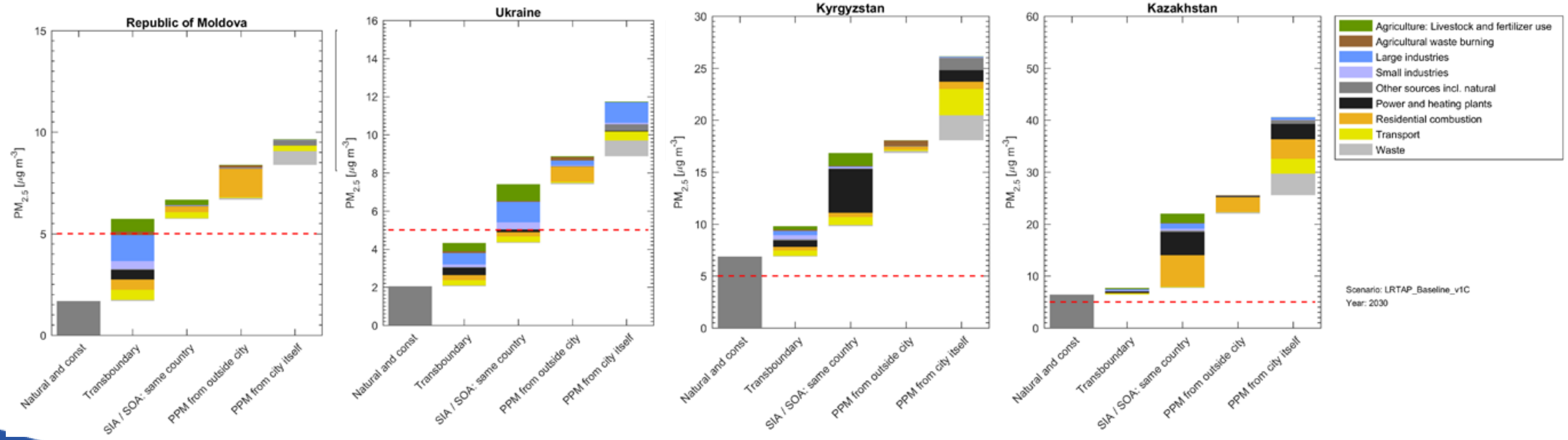
Preliminary results!

Country means: 2030, Current Legislation Scenario



Projections

- Based on PRIMES (EU + 9East) & IEA WEO STEPS
- without considering effects of Covid or war in Ukraine!



- Decreases in power and residential sectors
- Still high concentrations expected under CLE

Preliminary results!

Conclusions & next steps

- Preliminary implementation of new transfer coefficients for the extended domain done
- Complemented by grid to grid tracking for PPM to derive sector specific transfer coefficients and splits for urban areas
- Preliminary city specific contributions have been derived for ~300 cities in Europe+ (175 non-EU)
- Contributions depend strongly on the quality of the underlying emission patterns. Thanks to the methodology, there is room for improvement – data on urban/rural splits needed!
- In WB & EECCA, residential emissions and power/heating plants dominate; local contribution is often higher than in Western Europe. CLE brings decreases but does not solve the situation.
- Next steps:
    - Refine urban/rural distribution of residential sector
    - 5-year average for sectoral transfer coefficients
    - Split of ‘FSUA’ region in GAINS = Turkmenistan, Tajikistan, Uzbekistan
    - Split of SIA contribution from cities
    - Downscaling based on uEMEP

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