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Progress in modelling city level air pollution in GAINS

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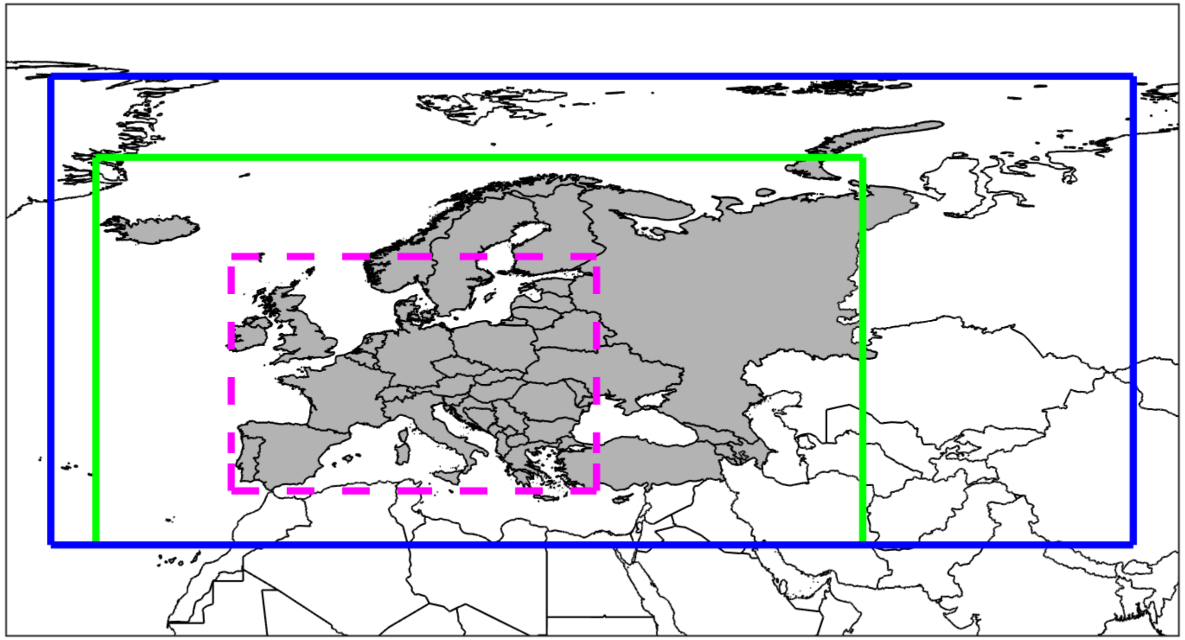
Domains in GAINS



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)

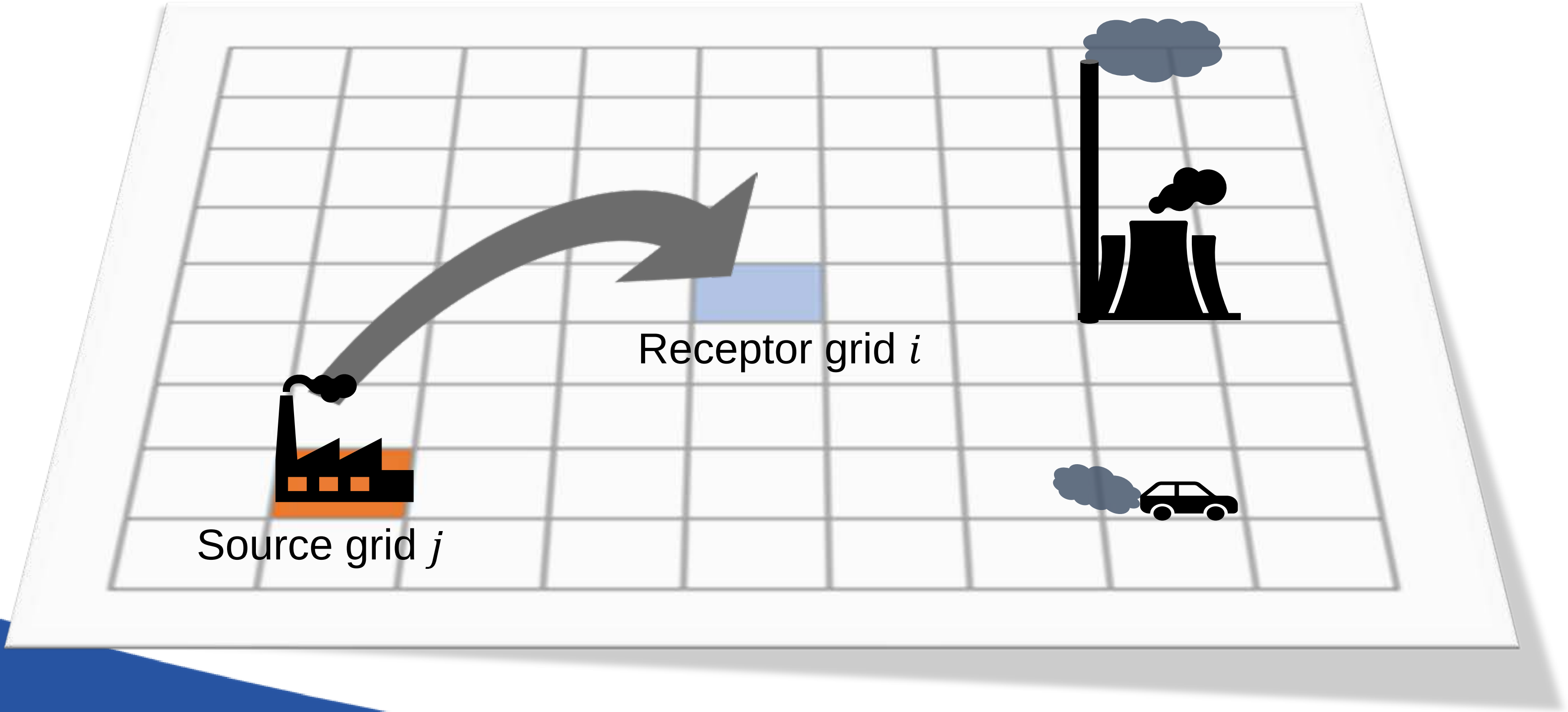
New transfer coefficients in GAINS

- Extended EMEP domain
- Resolution: 0.3°x0.2°
- Base case: 2030 Baseline scenario
- Reduction simulations for 50 countries (incl split of Turkmenistan, Uzbekistan, Tajikistan) and 10 sea regions (5 seas, inside/outside 12nm)
- 5 met years
- 5 source pollutants (PPM, SO_2, NOx, NH_3, VOC)
  - Separate reduction for soil NOx
  - 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

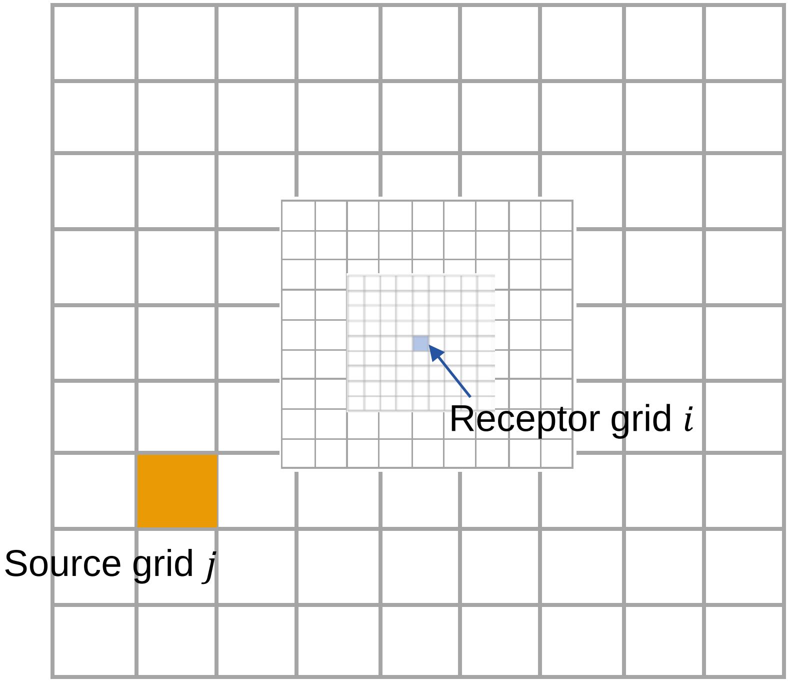


Extension with grid-to-grid tracking of PPM

- 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°)

Sector specific transfer coefficients (0.1°)

20 grid cells in each direction => Complete domain coverage



Combination: Sector specific transfer coefficients

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

  From source regions r, source pollutant p, to $PM_{2.5}$ 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 0.1^0, 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 $[PM_{2.5}]_{i,scen} = \delta_i + \sum_s \sum_r \sum_p Emis_{r,s,p,scen} \cdot T_{r,p,s,i}$

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

Downscaling based on uEMEP

- uEMEP was run on 250m × 250m resolution (Western and Central-Eastern Europe)
- Important for GAINS: increment in population exposure beyond the 0.1° resolution
- Exposure increment for PPM for road traffic and residential sectors applied to the local fraction of PPM

$$PPM_{popwgt} = \sum_{r'} \sum_{s} E_{PPM,r',s} \cdot T_{r',s,i} + \sum_{s \in \{TRA,RES\}} E_{PPM,r,s} \cdot TLoc_{r,s,i} \cdot Incr_{r,s,i}$$

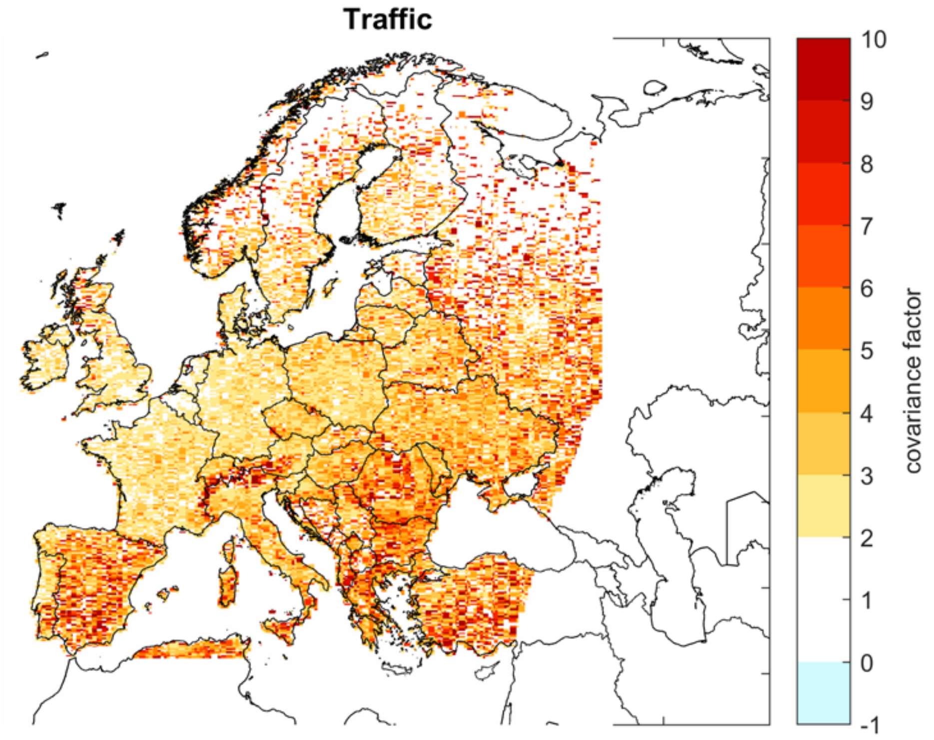
with r... region, s... sector, i... 0.1° receptor grid,

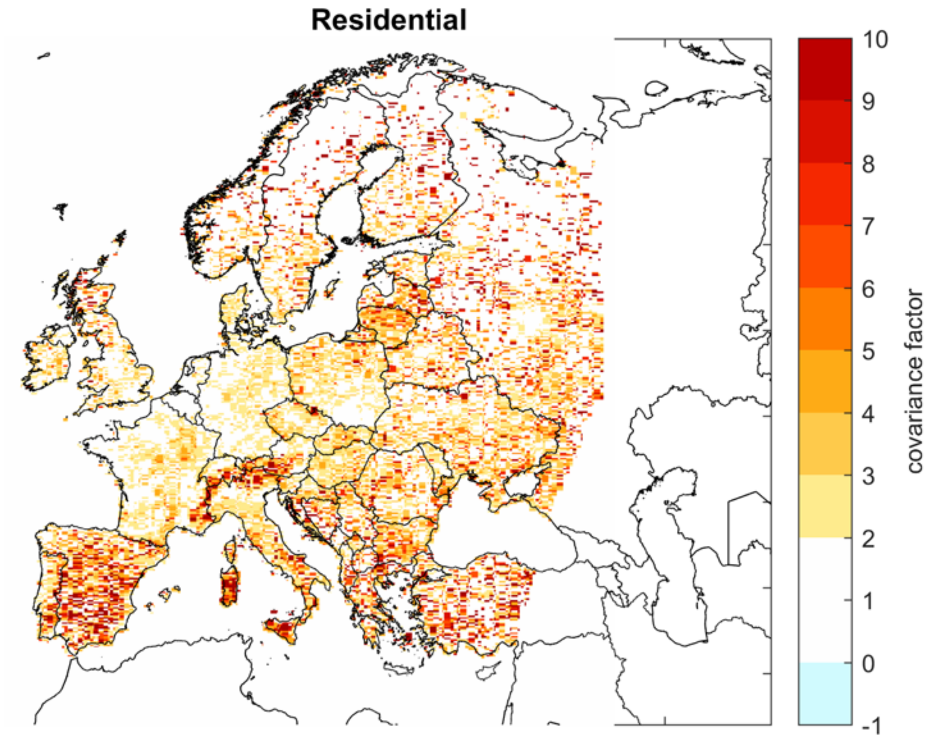
T... transfer coefficient, $TLoc$... local transfer coefficient, $Incr$... increment factor (uEMEP)

- Accounts for:
  - Spatial re-distribution - Proximity of emission sources to population.
  - Correction of vertical concentration profiles (Near-ground emission release)
- Particularly in smaller towns, PM_{tot} > $PM_{0.1}$. In larger cities the effect is smaller.

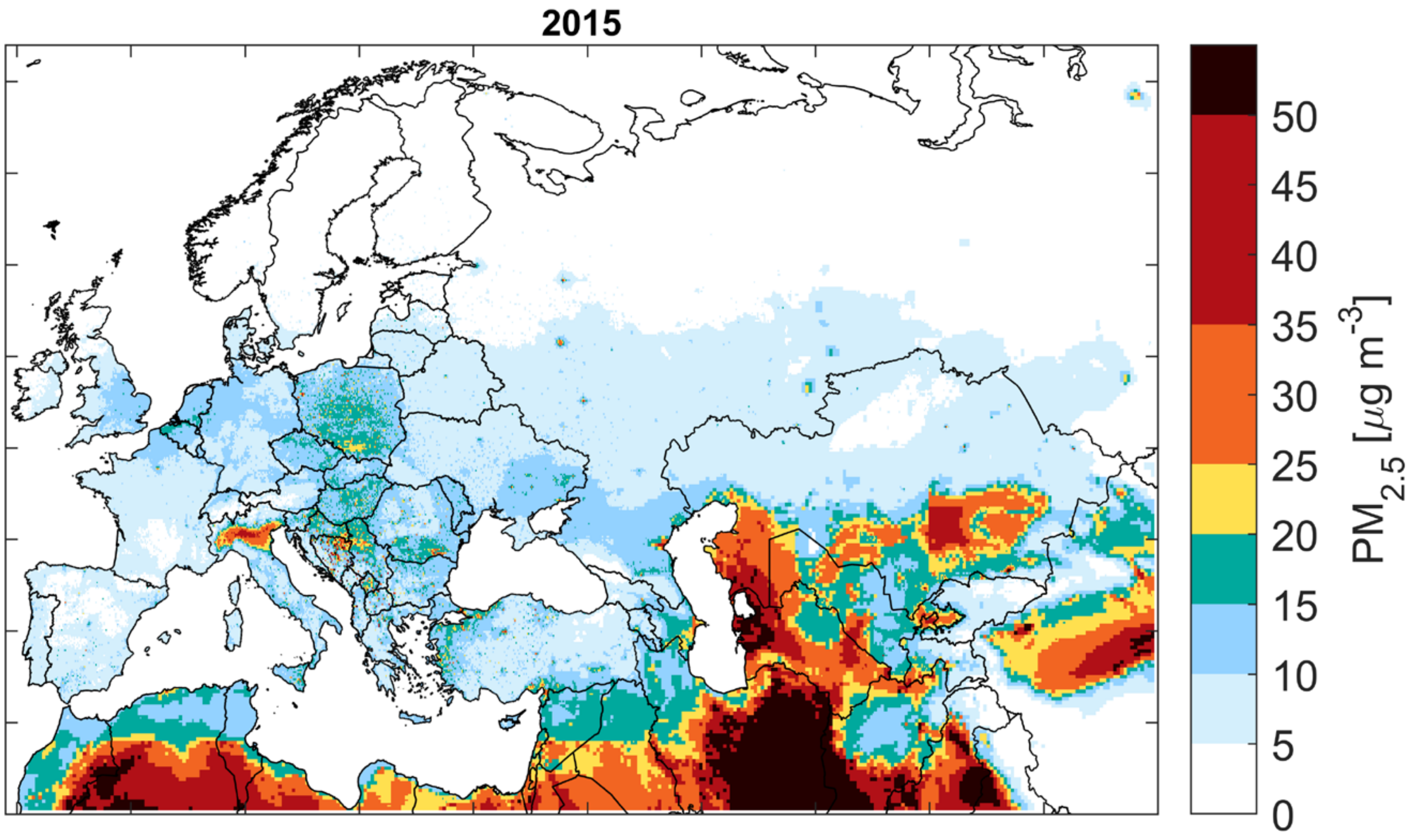
Exposure scaling factors from uEMEP

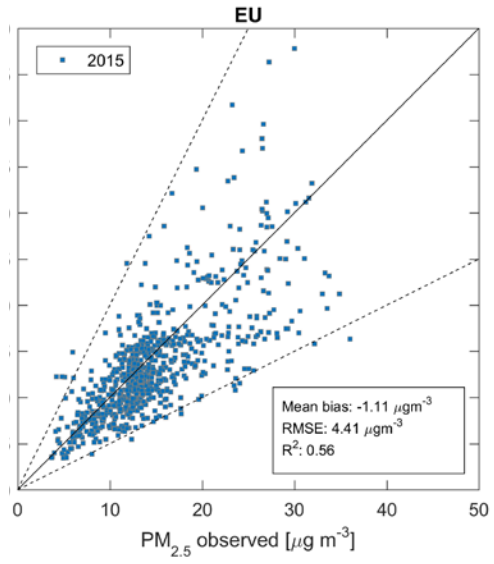
= change of total population-weighted surface PPM in each 0.1° grid when using the 250m resolution, compared to 0.1° resolution





Ambient $PM_{2.5}$ concentrations

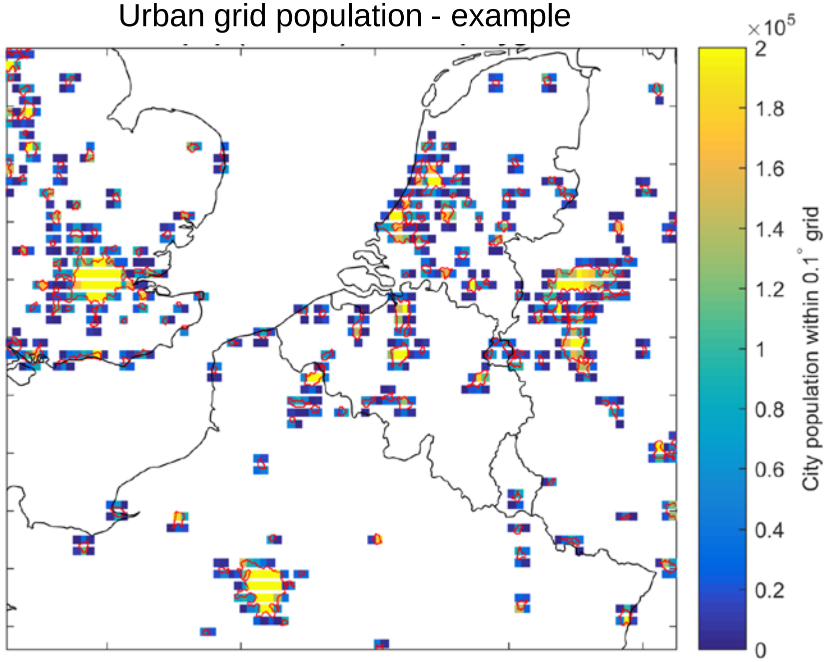




Contributions to $PM_{2.5}$ in cities: Approach

- 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: JRC GHS urban core shapes (UCDB), consistent with the 250m population

Urban grid population - example



- 1270 cities > 50,000 inhabitants in the extended GAINS-Europe domain
- Recent addition: downscaling based on uEMEP implemented

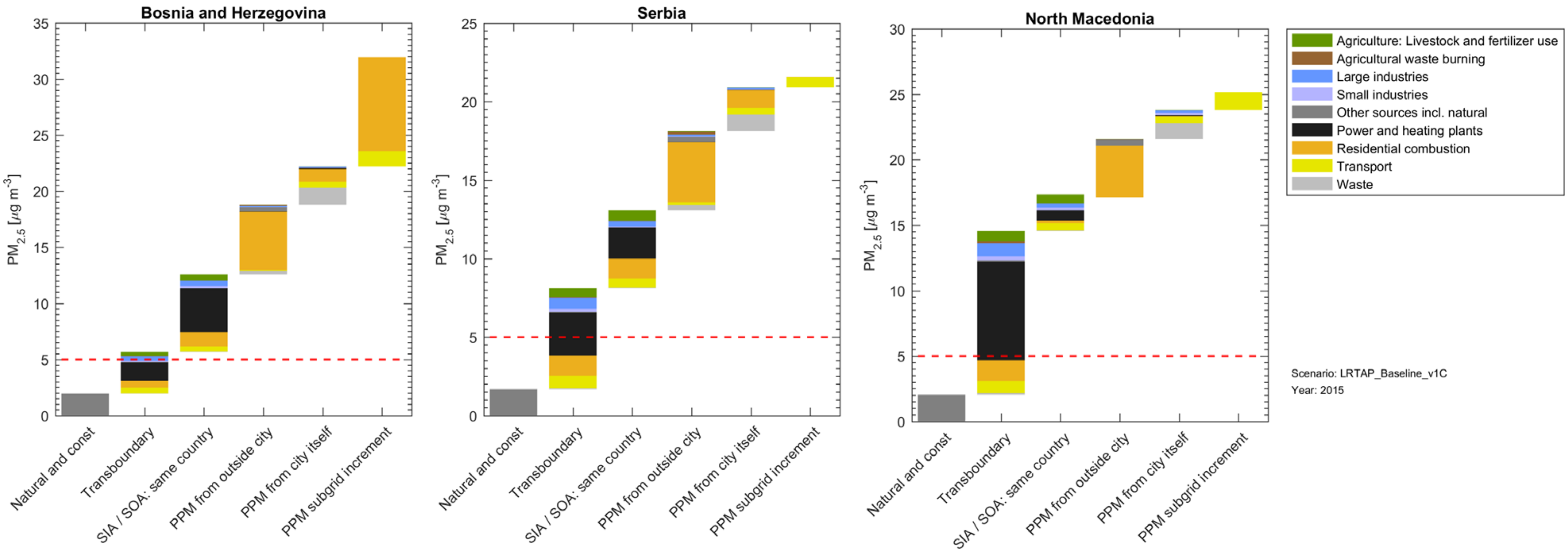
Key scenarios analyzed during review of Gothenburg Protocol

All scenarios developed for air pollutants and methane up to 2050

Aligned with recent analysis for the EU (AAQD Impact Assessment and Clean Air Outlook 3)

- *Baseline*
  - Review of the recent policies and measures and national implementation progress and plans
  - Energy, industry, and agriculture for (i) the EU – Green Deal (Fit for 55), (ii) West Balkan and selected EECCA using the same modelling tools as for EU, (iii) remaining countries – IEA &FAO
- Maximum technically Feasible Reduction '*MFR*'
- Alternative '*Low*' scenario
  - Climate policies compatible with Paris goals; for the whole region
  - *MFR* for air quality, including shipping sources
  - Behavioural changes - dietary changes (lower meat protein consumption)

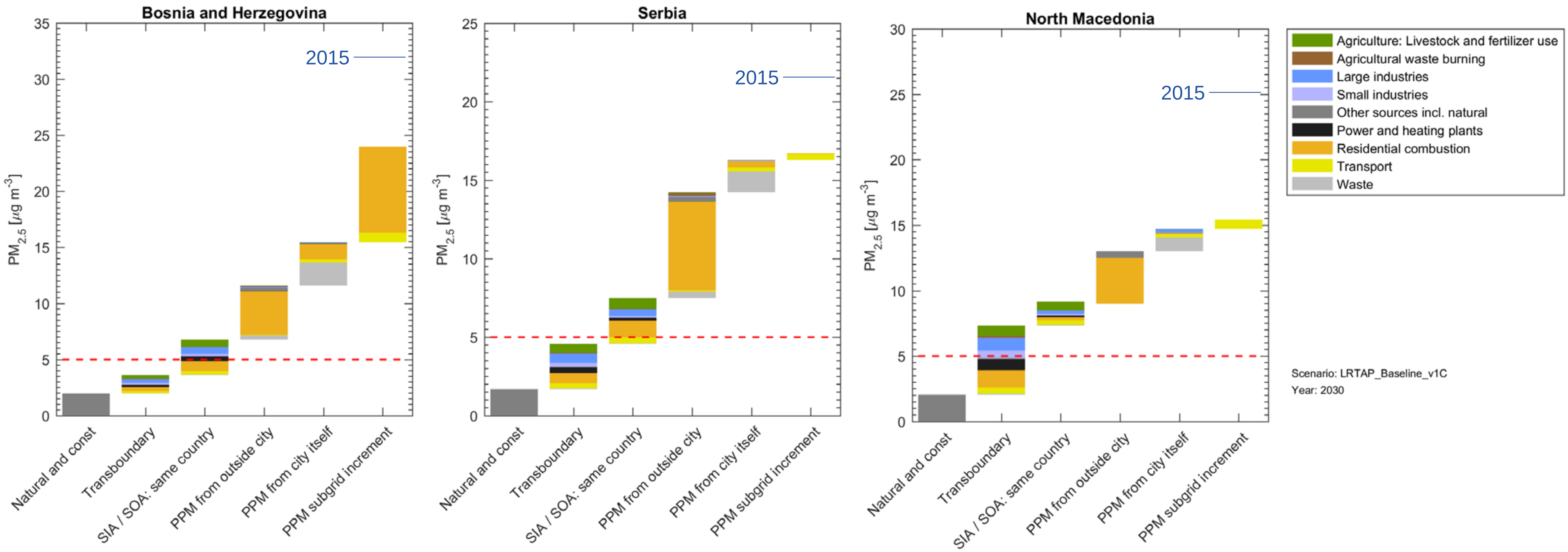
Country averages of cities, W Balkan: 2015



Many countries face higher concentrations than in EU.
Larger role of residential and power sector.

Preliminary results

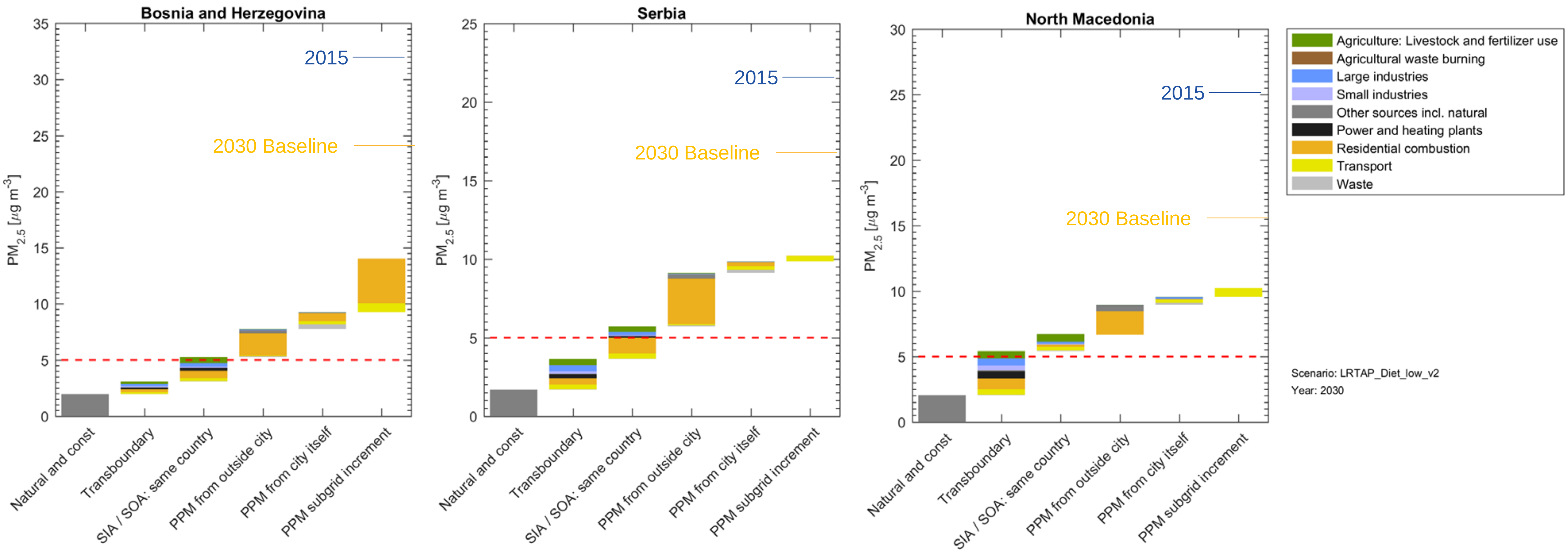
Country averages of cities, W Balkan: 2030 Baseline



Only moderate decreases under current legislation. Notably control of power sector in West Balkan

Preliminary results

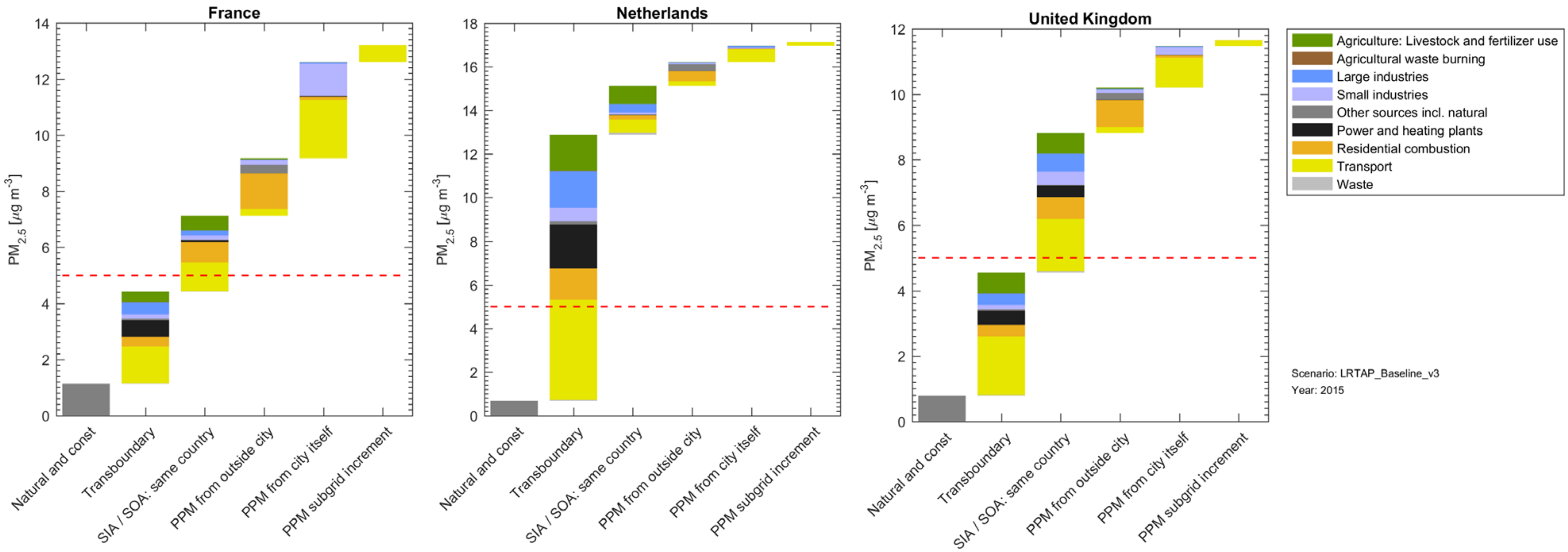
Country averages of cities, W Balkan: 2030 LOW



Further mitigation feasible but limited within short time and concentrations remain above WHO 2021 AQG

Preliminary results

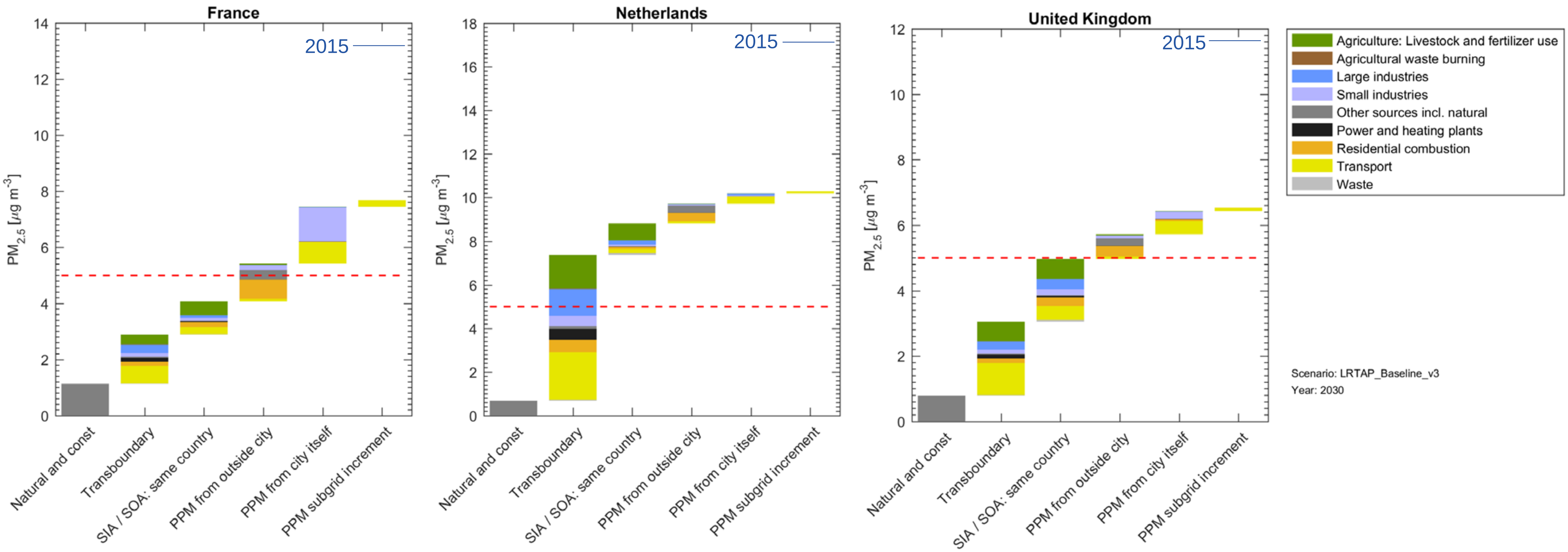
Country averages of cities, EU: 2015



Important role of SIA and transboundary (also mostly SIA) in NL, UK

Preliminary results

Country averages of cities, EU: 2030 Baseline



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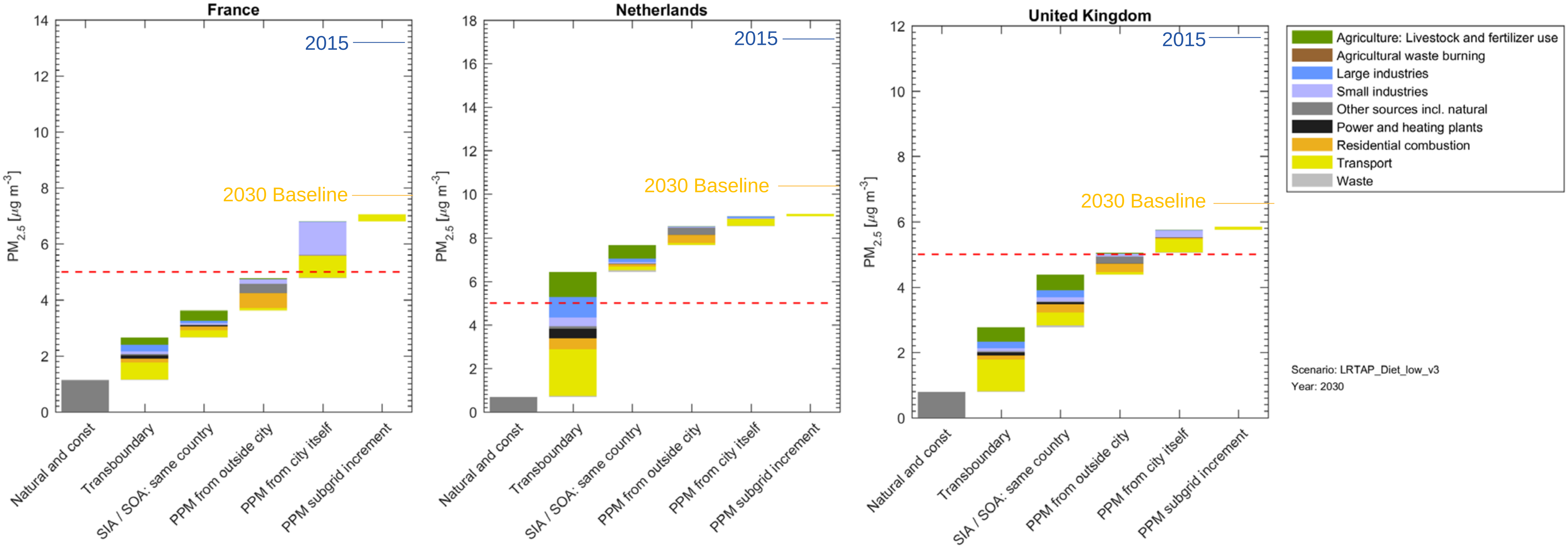
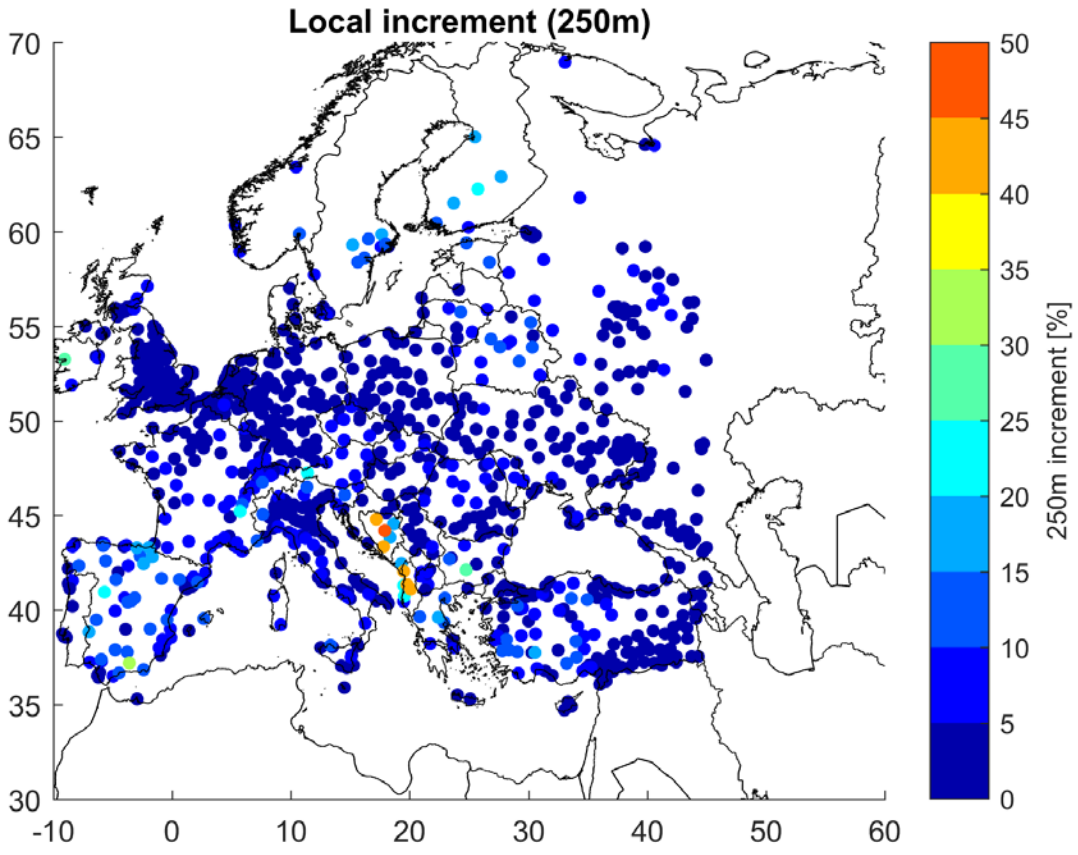


Important role of SIA and transboundary (also mostly SIA) in NL, UK

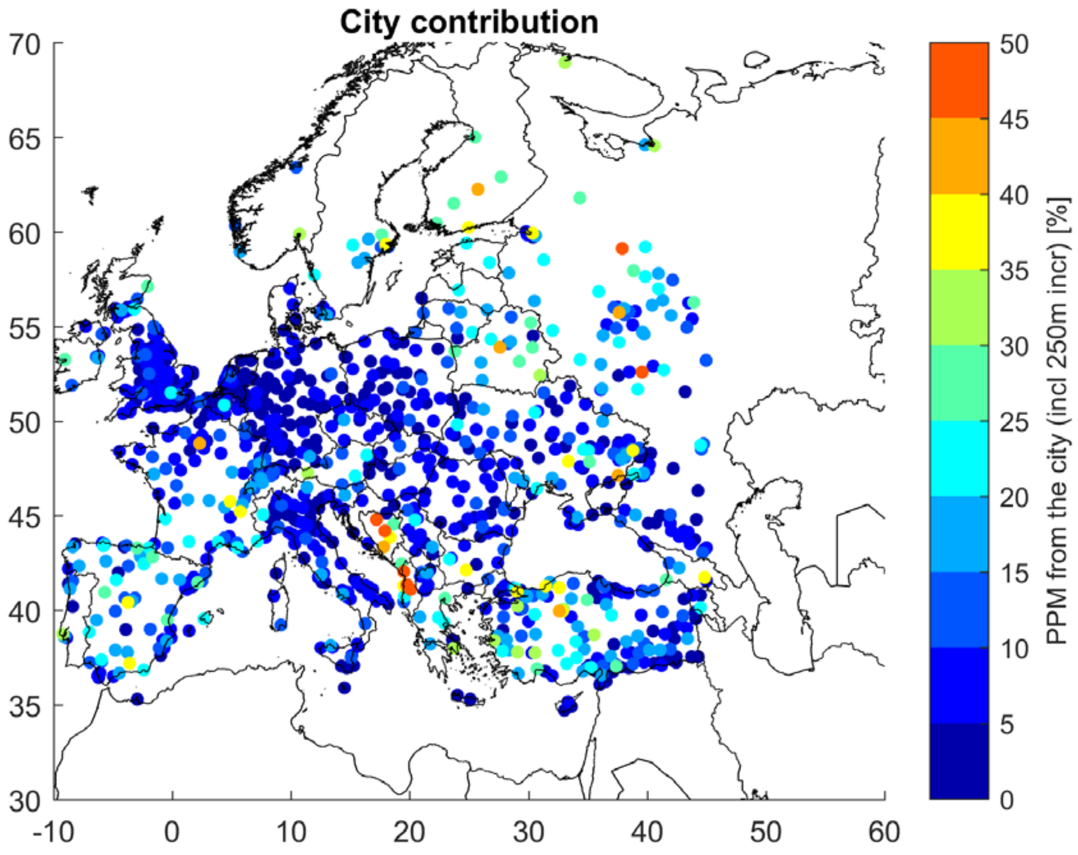
Preliminary results

How much does the local (250m) increment matter?



Can be large in places with smaller cities and residential solid fuel burning!

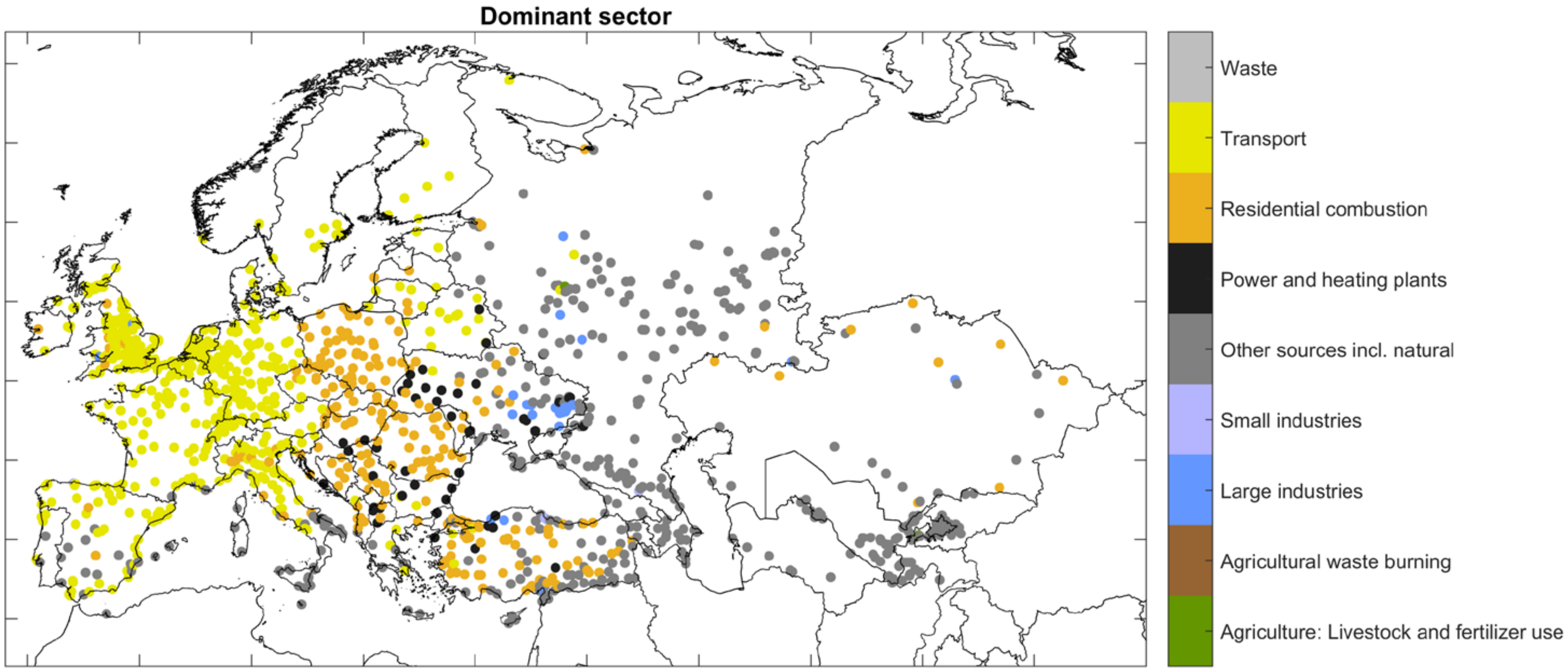
How much does the city contribution (PPM) matter?



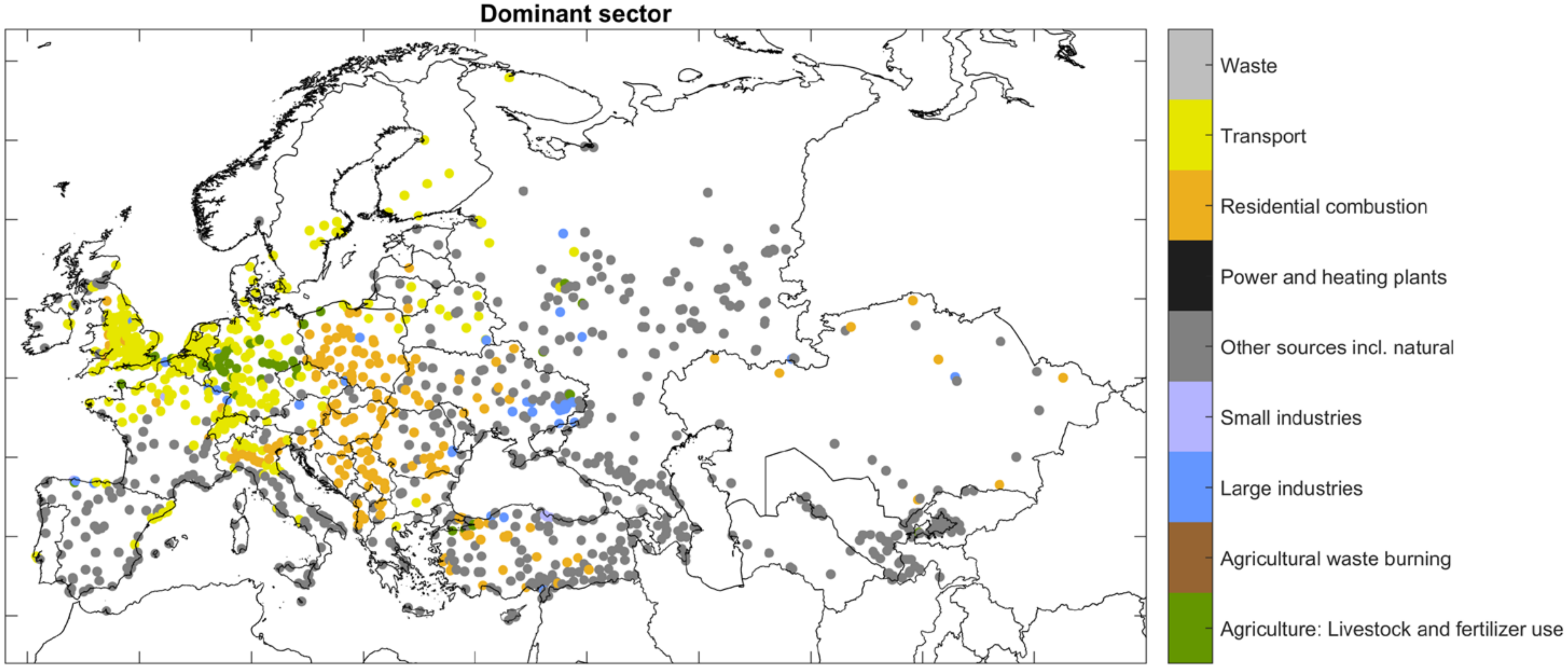
Local contribution varies strongly. Particularly large (>40%) only in

- Part of Balkans (BIH, Albania)
- Few megacities
- remote cities

Dominant sector (2015)

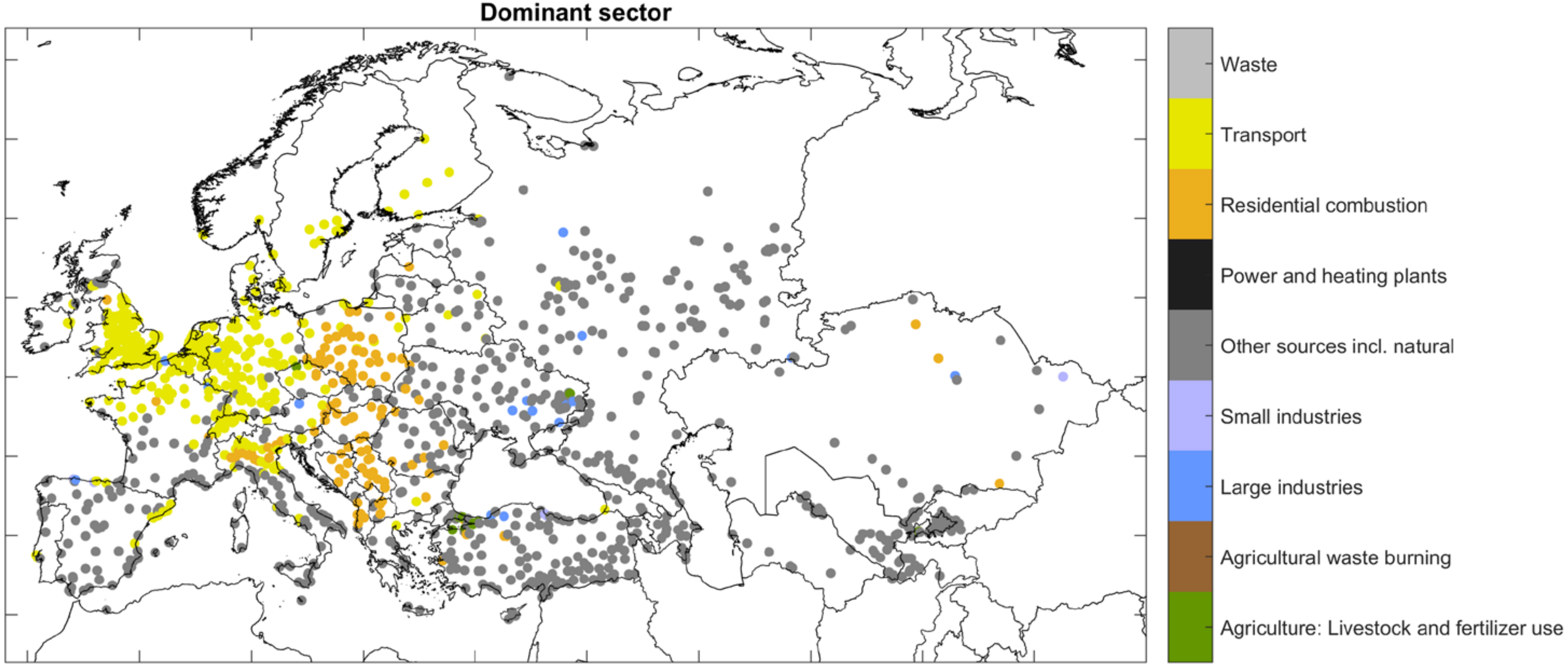


Dominant sector (2030 Baseline)



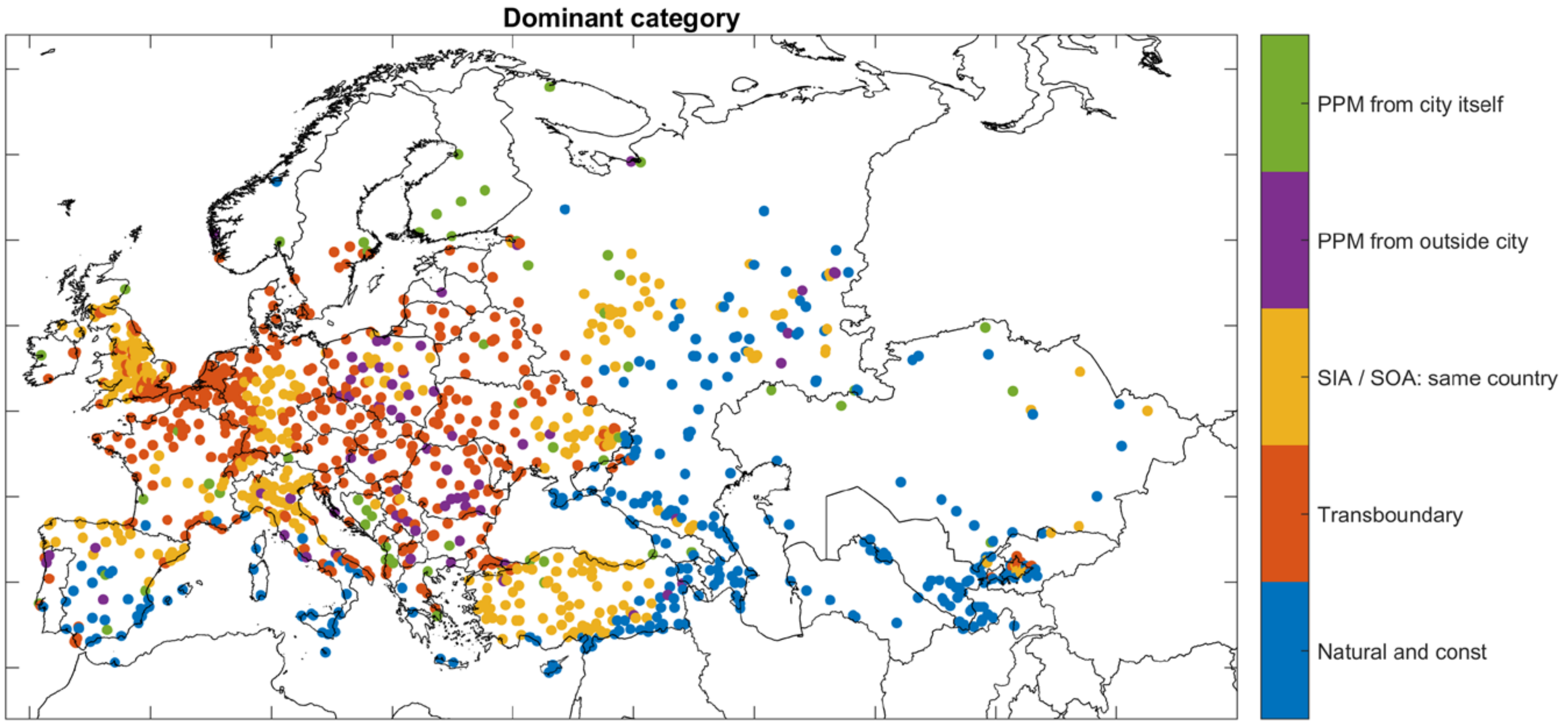
- Power sector disappears as leading contributor in SE / E Europe
- Agriculture more prominent in Germany
- Natural dust becomes more important in S / SE Europe with anthropogenic sectors better controlled

Dominant sector (2030 LOW)

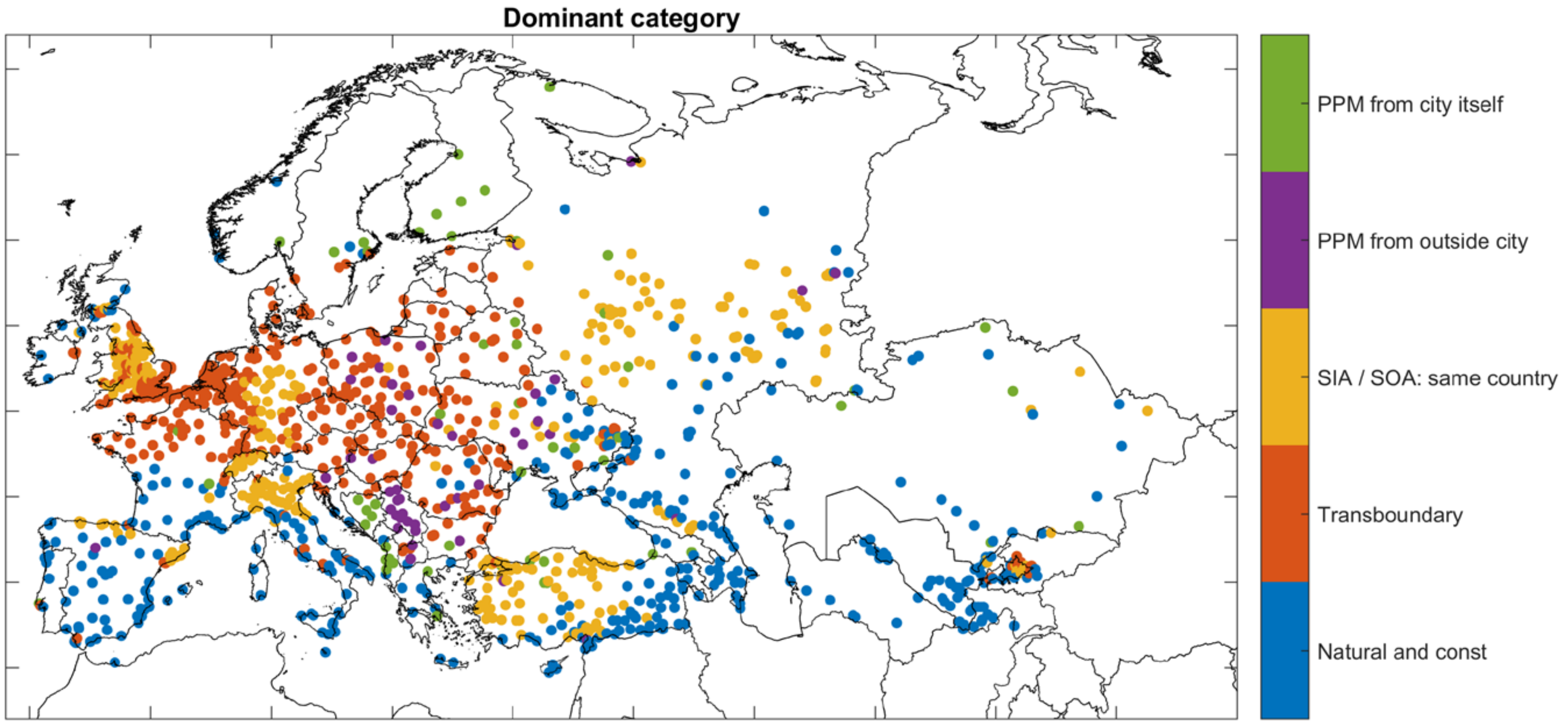


- Natural dust becomes more important in S / SE Europe with anthropogenic sectors better controlled

Dominant category: 2015

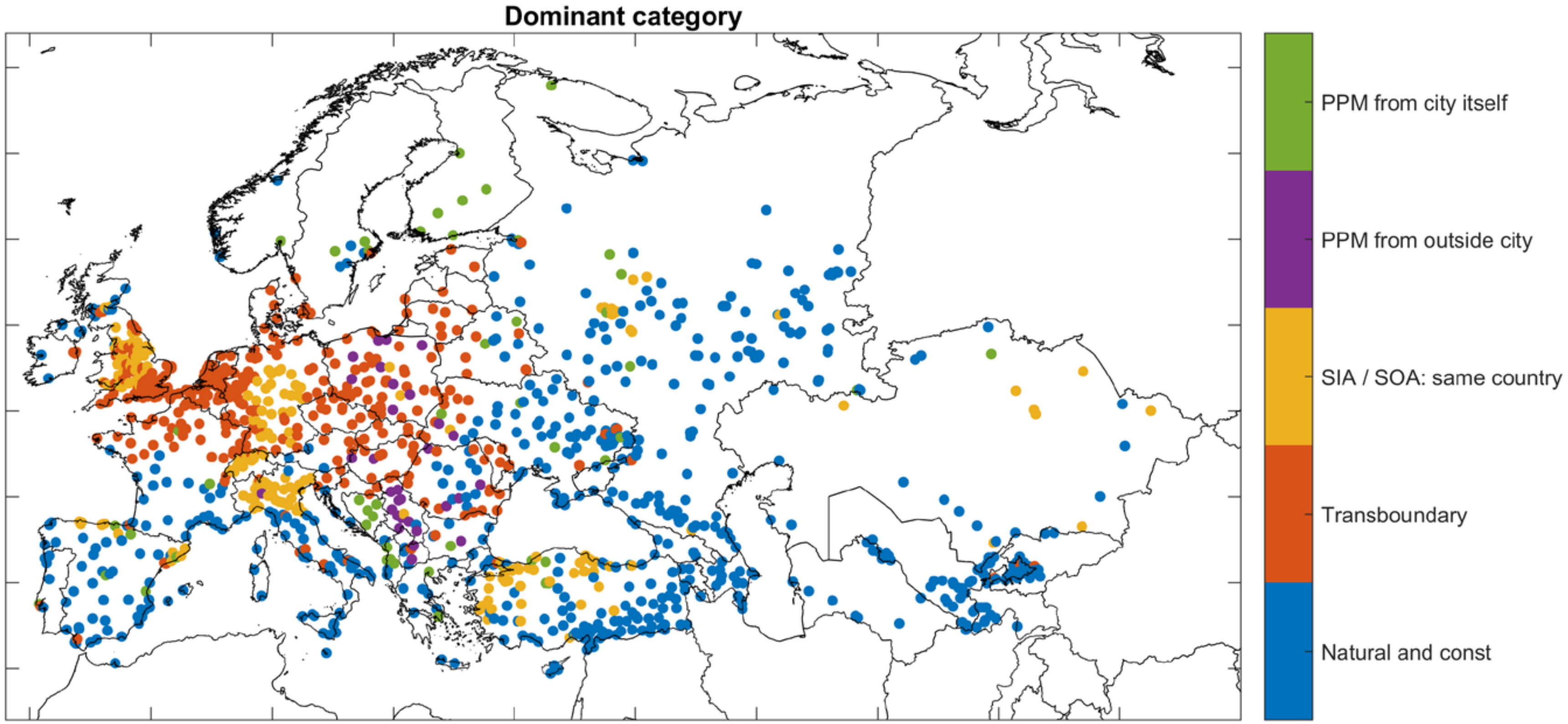


Dominant category: 2030 Baseline



Only limited changes in the importance of source categories

Dominant category: 2030 LOW



Natural sources (+SR constant) become dominant in some regions under LOW

Conclusions

- 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 (at 0.1°) have been derived for ~1270 cities in Europe+
- Contributions from cities vary – high local contributions in Balkans, low in W Europe
- 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 the EU, strong decreases of ambient PM in cities are expected by 2030 with current legislation, limited scope beyond (local measures not considered here!)
- In West Balkan & 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 problem; there is scope for significant further reduction.

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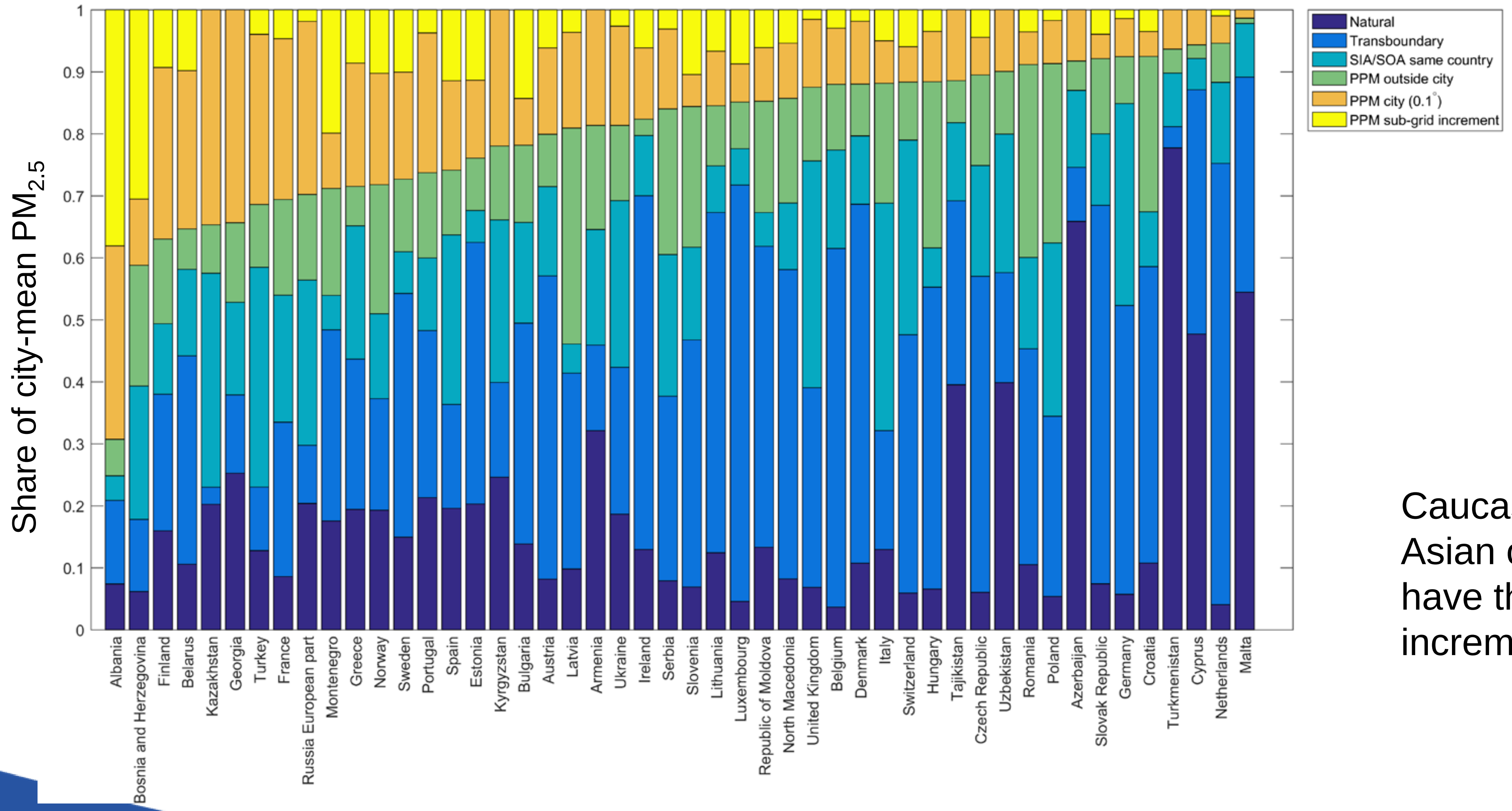
Thank you!

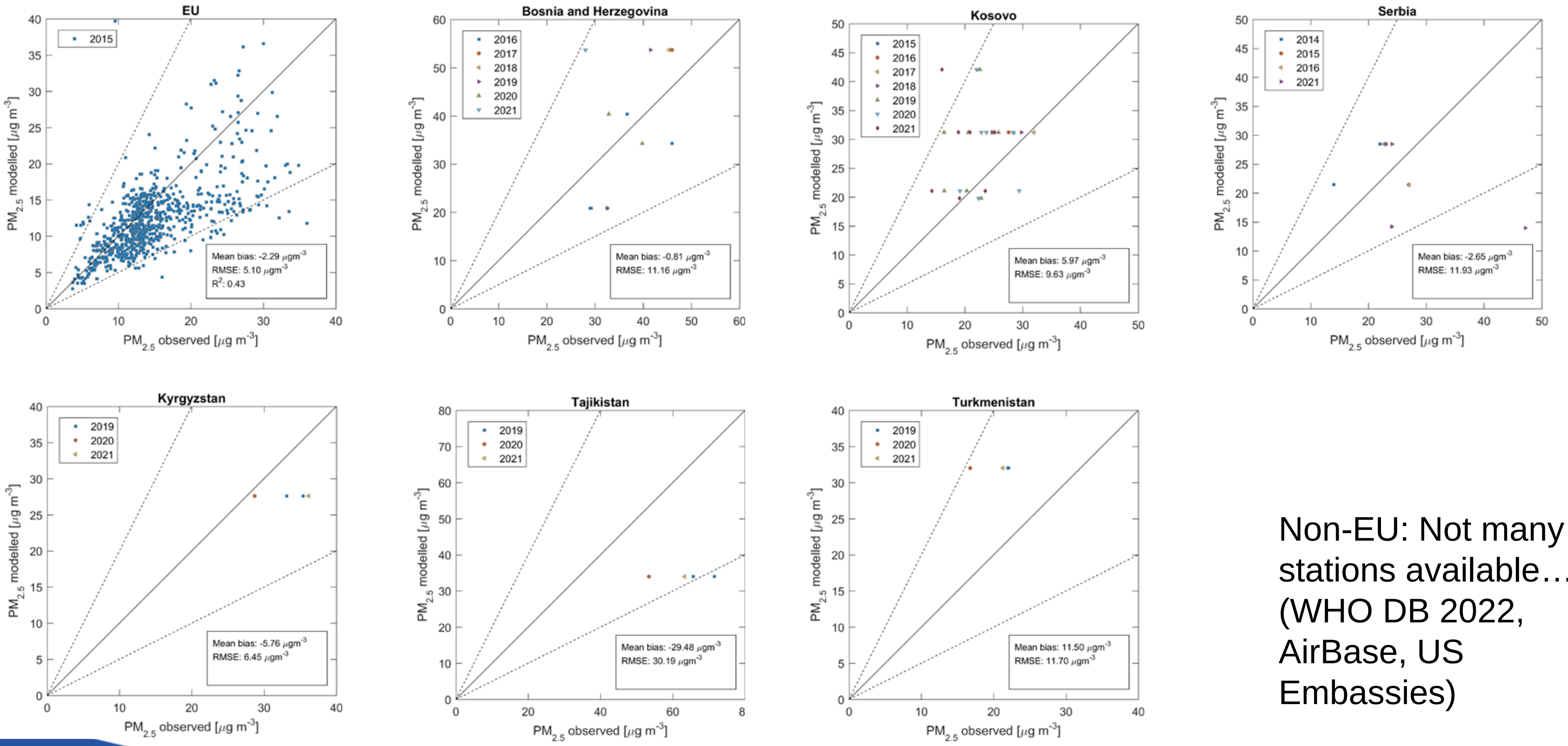
Name
Program
Email
Web

Importance of PPM city contribution (incl. increment, 2015)



Caucasus & Central Asian countries don't have the local increment yet.

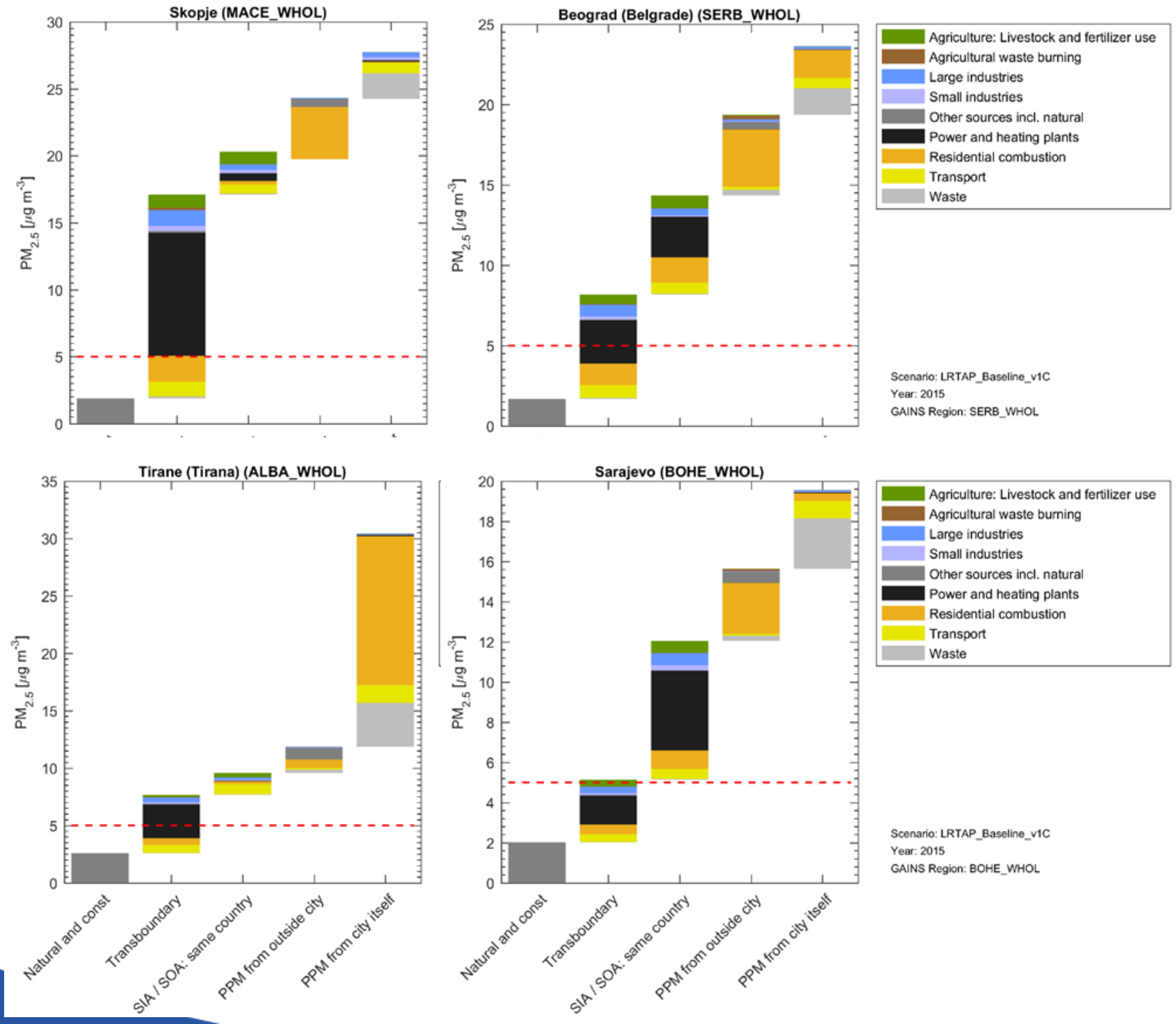
Ambient $PM_{2.5}$ concentrations – validation



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

Preliminary results!

Source contributions to cities: West Balkan (2015)



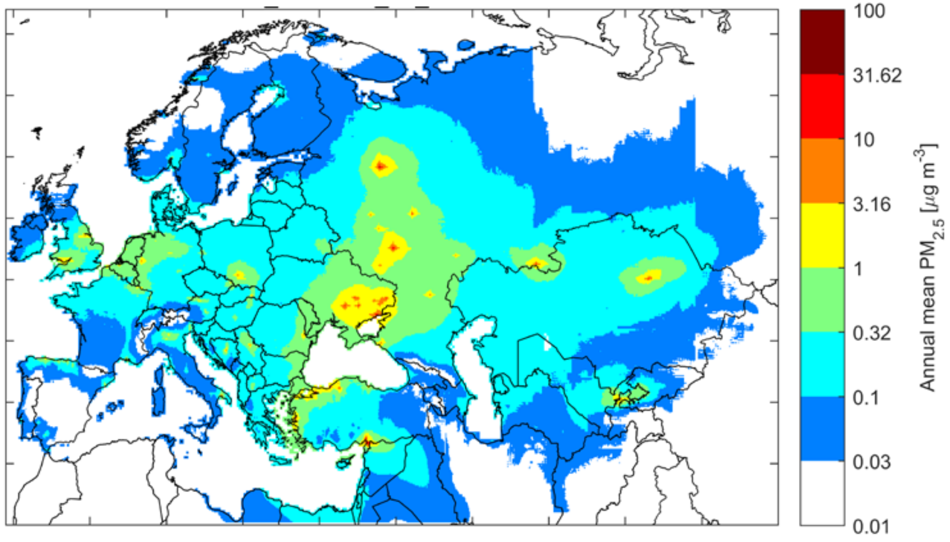
- Important role of power/heating plants
- Also residential sector

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

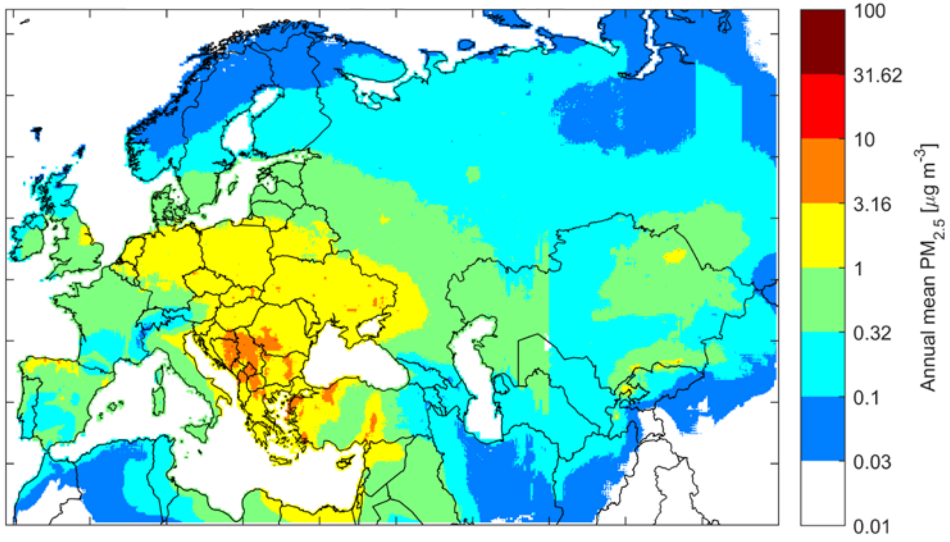
Preliminary results!

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

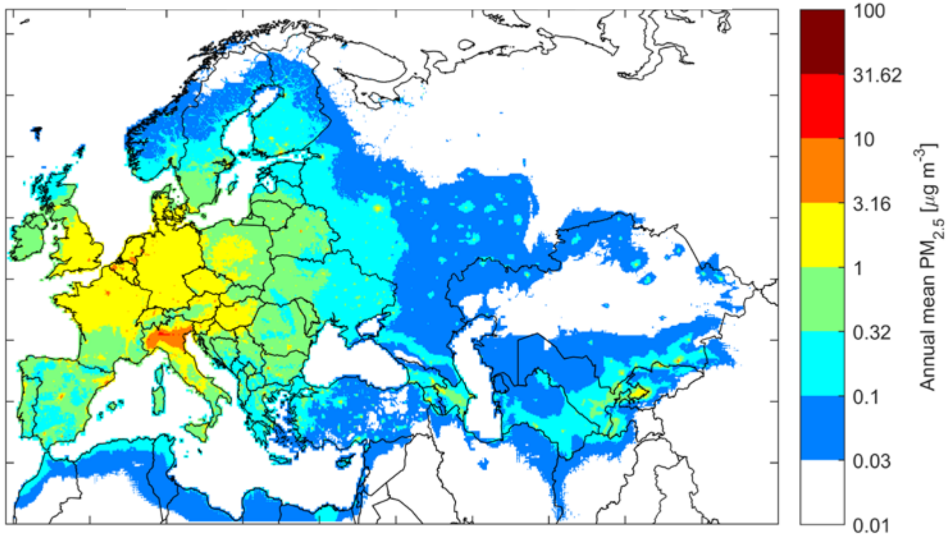
Iron & steel industry



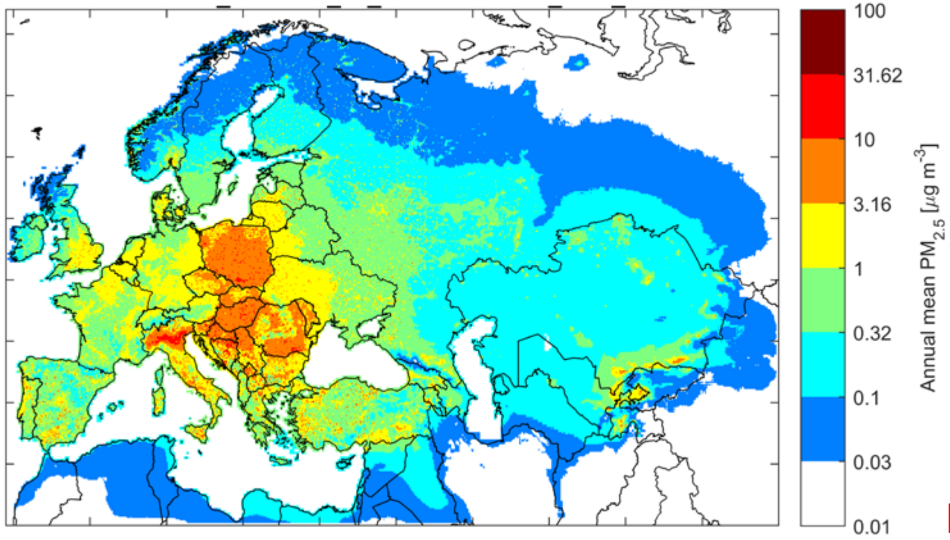
Coal power plants



Traffic: cars and light duty trucks



Rural heating



Done for ~40 sectors.

Preliminary results!

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^{0}, monthly results

  => sectoral transfer coefficients for PPM:

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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

$\mathrm{D}(r,s,l,j)$ … spatial emission distribution pattern

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- 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)