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A new approach towards $PM_{2.5}$ source apportionment in GAINS

Some lessons from South Asia

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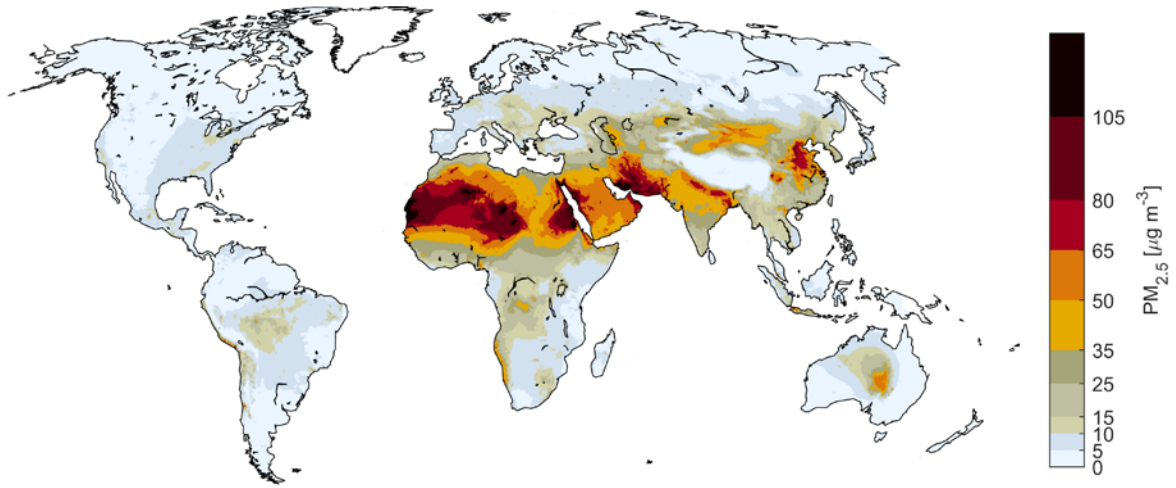
TFMM 2020 online meeting, 11 May 2020

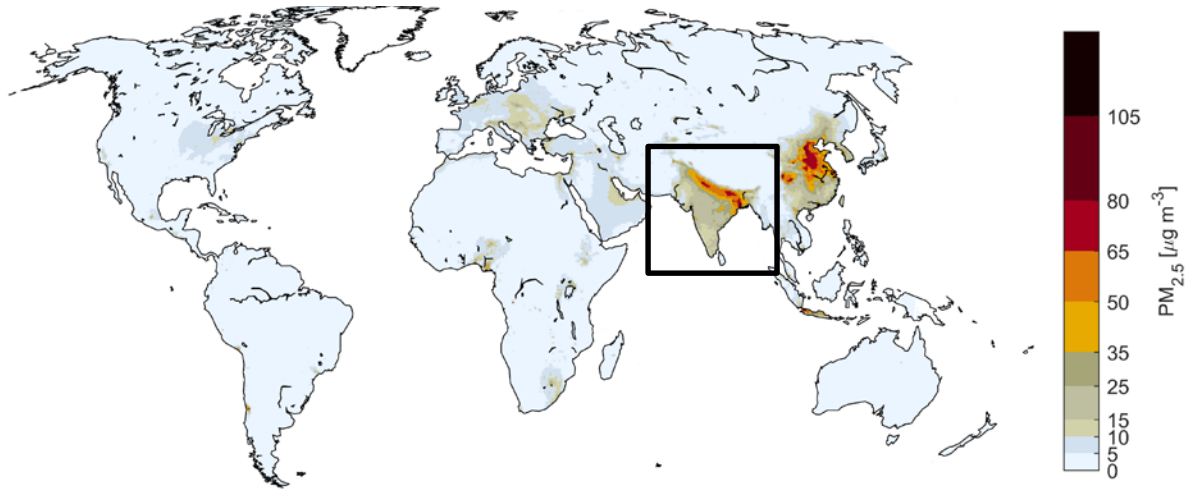
Introduction

- South Asian cities are among the highest polluted in the world
- Objective: Develop sectoral and spatial source apportionments for $PM_{2.5}$ in South Asia, for States and major cities

Total $PM_{2.5}$ (2015, GAINS)



Anthropogenic $PM_{2.5}$ (2015, GAINS)



Introduction

- South Asian cities are among the highest polluted in the world
- Objective: Develop sectoral and spatial source apportionments for $PM_{2.5}$ in South Asia, for States and major cities
- Quantify the local and imported shares of $PM_{2.5}$ for states and for major cities
- Explore suitable airsheds for joint air quality management

Methodology

- GAINS global transfer coefficients: linear approximation of EMEP CTM
  - 180 source regions globally (state level in India), region to grid, based on 15% reduction
  - high stack PPM and secondary PM precursors SO_2, NO_x, NH_3, VOC: 0.5º x 0.5º
  - Low level sources PPM, SO_2, NO_x: 0.1º resolution (with urban/rural source distinction)

- Grid to grid tracking ("local fraction") of PPM with EMEP CTM at 0.1º, monthly results, 2015, within ±8º of each receptor grid

  => sectoral transfer coefficients for PPM (currently only for lowest vertical layer):

$$T_{r,s,g} = \frac{1}{12} \cdot \sum_{m=1}^{12} \sum_{g'} \gamma(r,s,g')\, \tau(s,g',m)\, G(g',g,m)$$

r … source region, s … source sector, g … receptor grid cell (0.1^0), g' … emission grid cell (0.1^0)

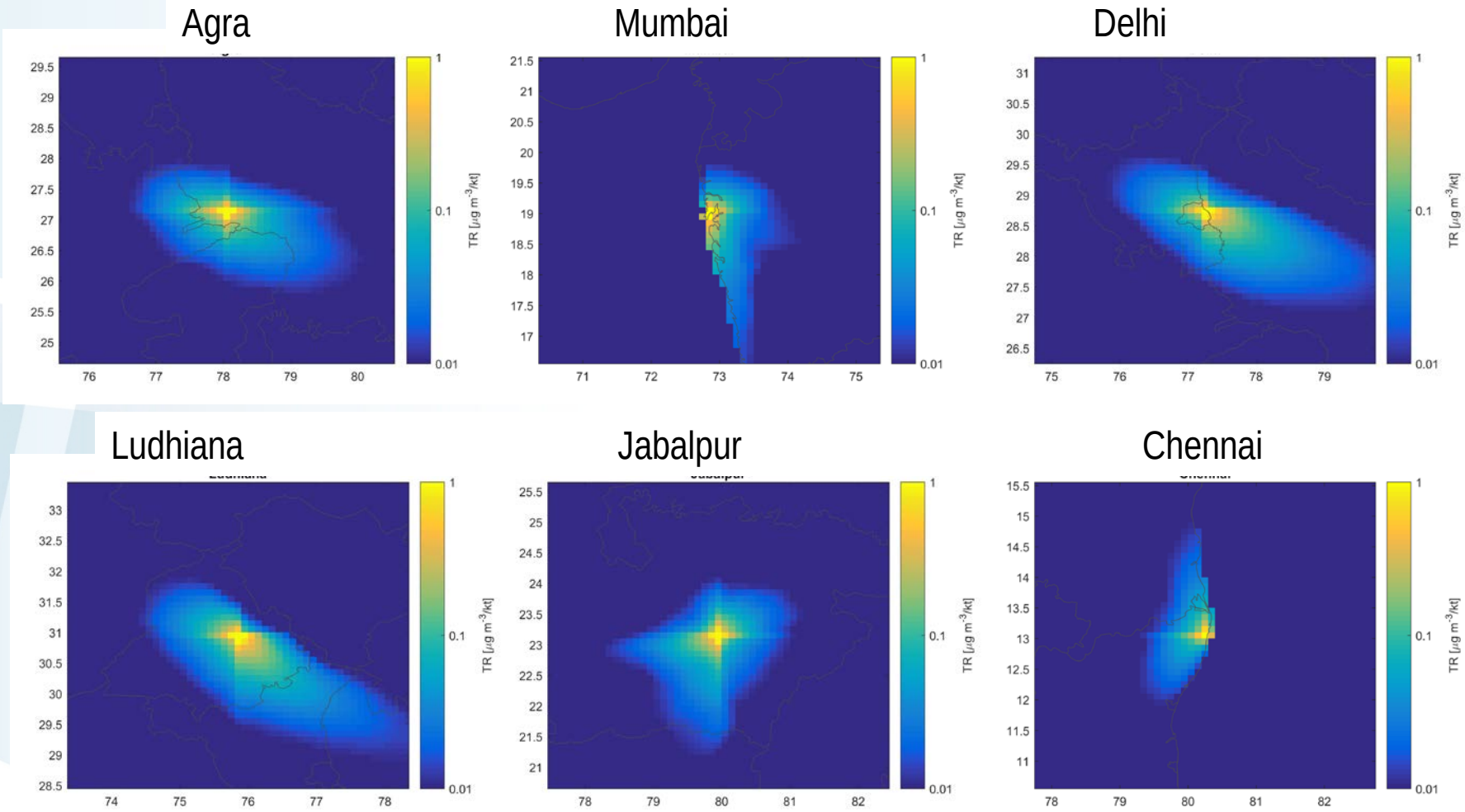
$\gamma(r,s,g)$ … spatial emission distribution

$\tau(s,g,m)$ … temporal (monthly) emission share

$G(g',g,m)$… grid-to-grid transfer coefficient from g' to g in month m

Fine-scale dispersion of low-level PPM emissions

- Examples of dispersion patterns of low-level PPM emissions from cities

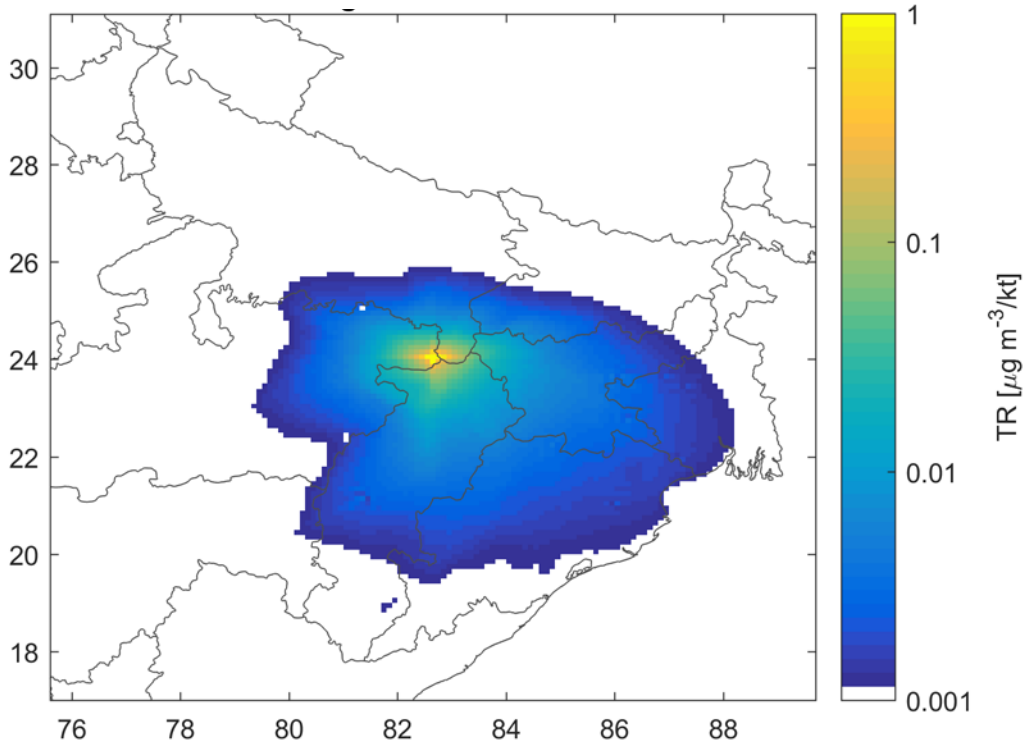


This enables analyses for individual cities!

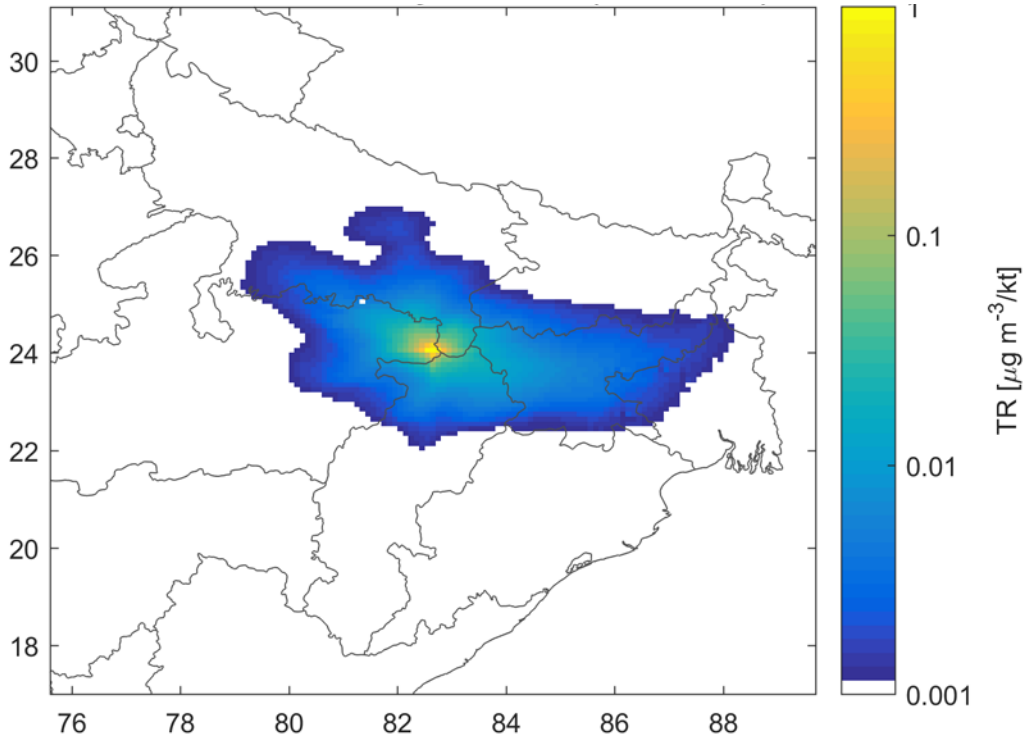
Sectoral transfer coefficients

Annual mean dispersion pattern of PPM from 1 grid cell…

Domestic sector: ground level (0-50m)



Brick kilns: 0-90m, only in operation in dry season



Temporal emission patterns matter!

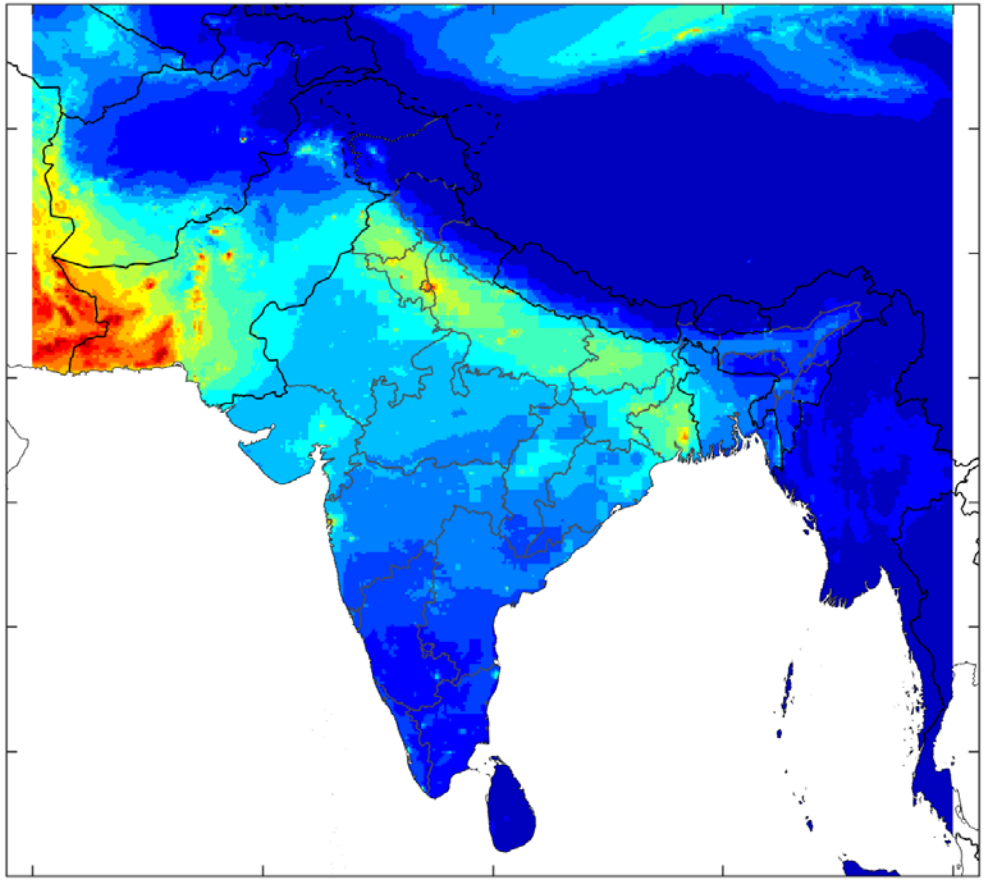
Recent improvements in emission inventories

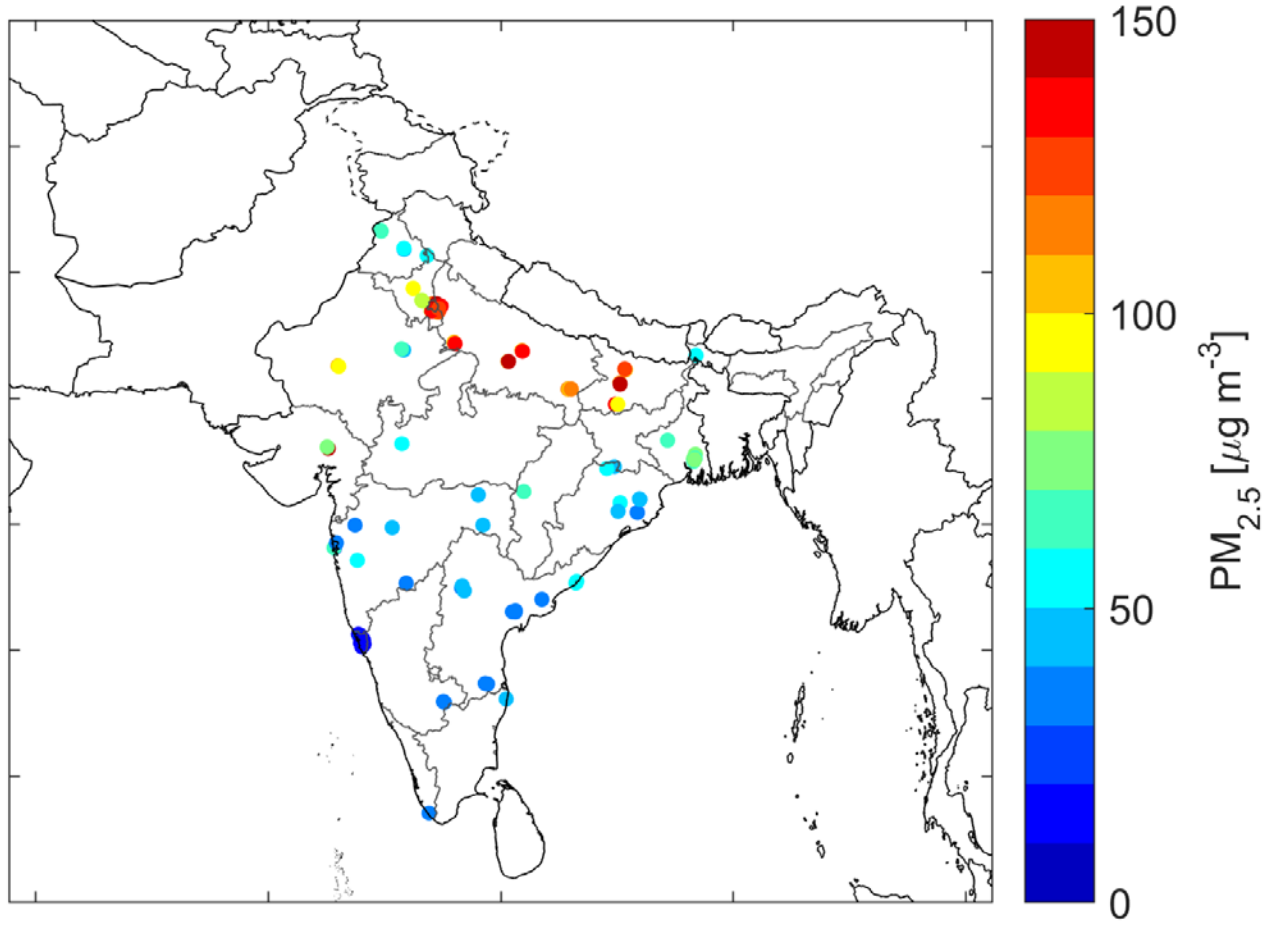
- Brick kilns
  - New spatial and temporal patterns
- Burning of agricultural residue
  - New spatial and temporal patterns derived from recent remote sensing products,but uncertainties about volumes remain
- Municipal waste burning
  - New estimates of waste quantities, burned volumes and locations
- Road transport
  - New data on traffic intensities by state, road maps, road dust non-exhaust emissions, urban/rural shares, real-life emission characteristics, recent control legislation

Total $PM_{2.5}$ concentrations

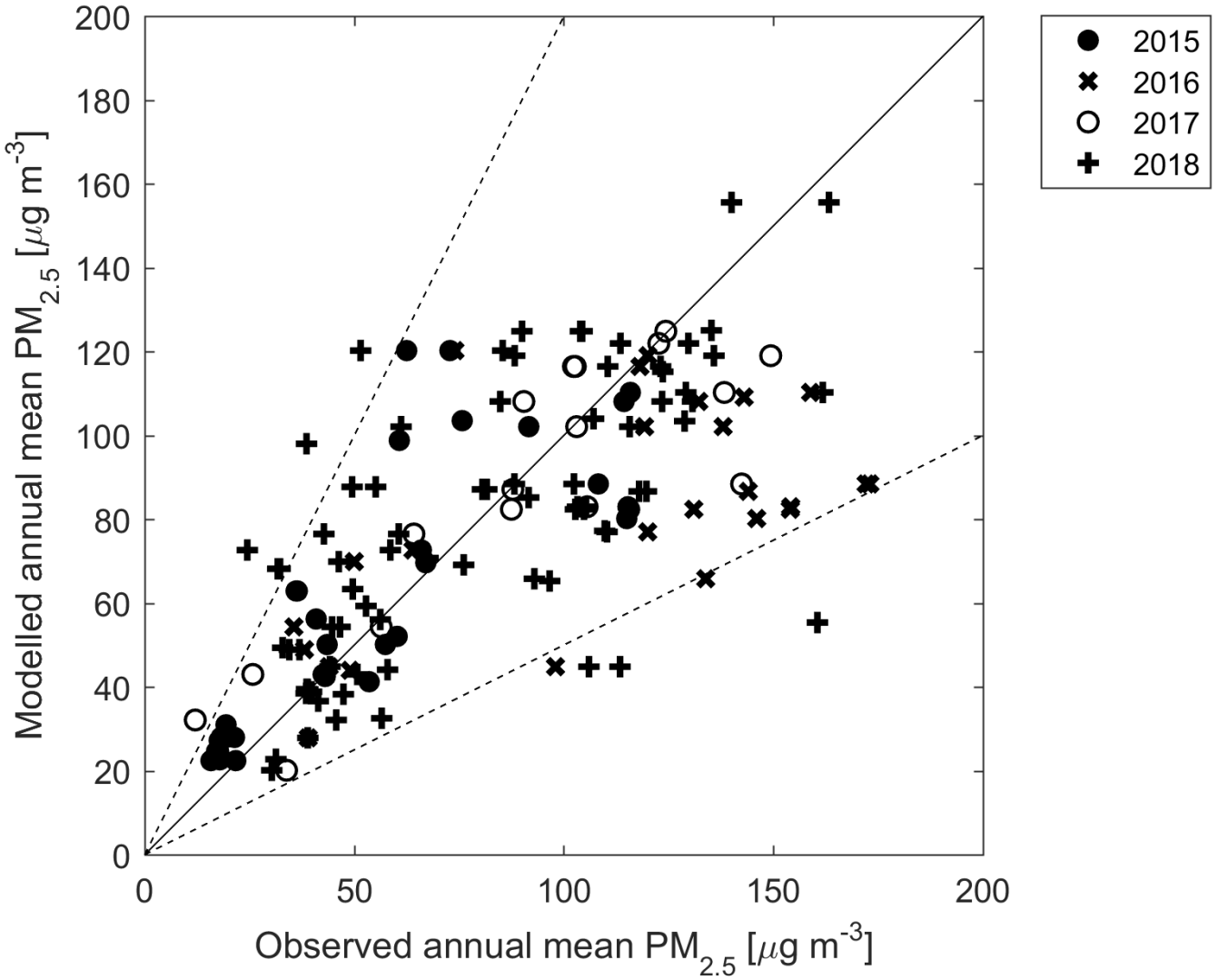
GAINS, 2015

Observations, 2015-2018





Validation of model estimates - India



Note that model calculations were conducted for 2015 meteorology with 2015 emission estimates.

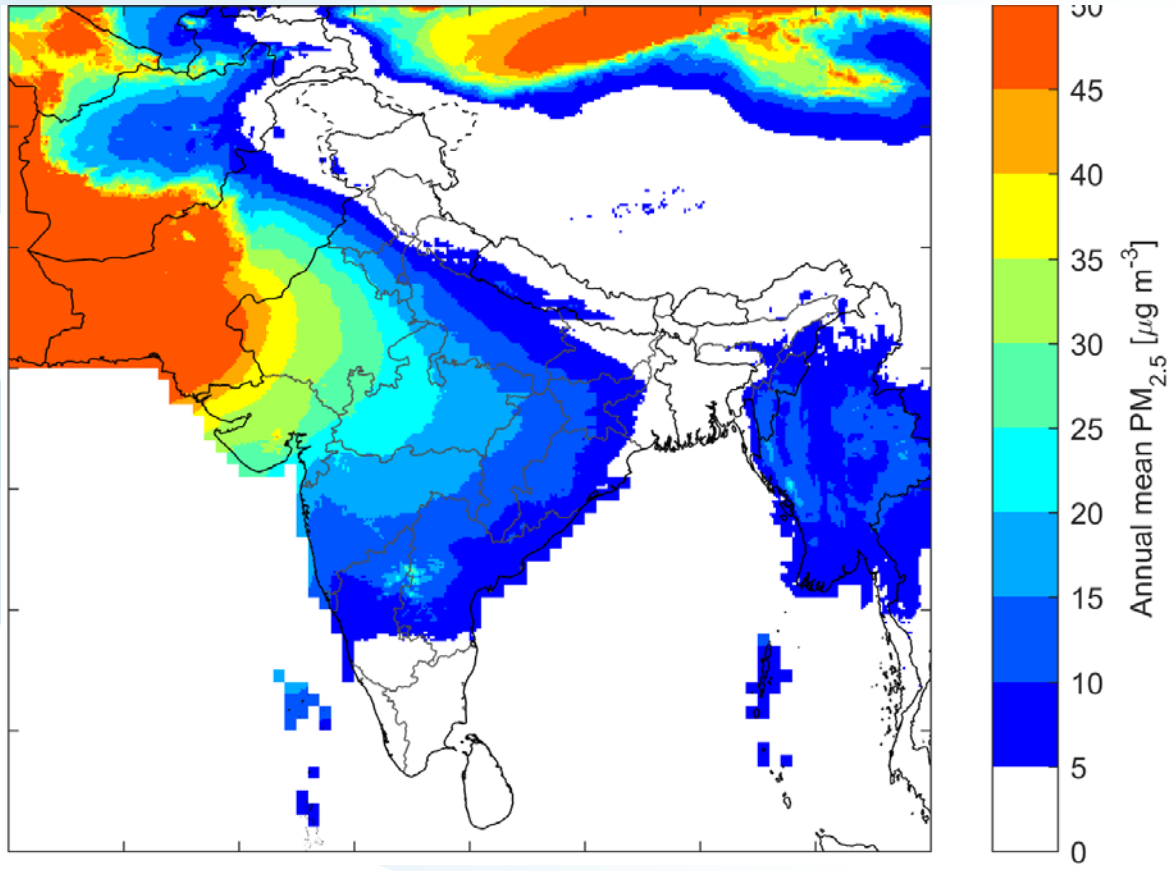
All monitoring data ($PM_{2.5}$ only, 2015-2018) were extracted from CPCB web site, only stations holding data for 11-12 months with more than 21 days/month considered .

Sectoral contributions to $PM_{2.5}$

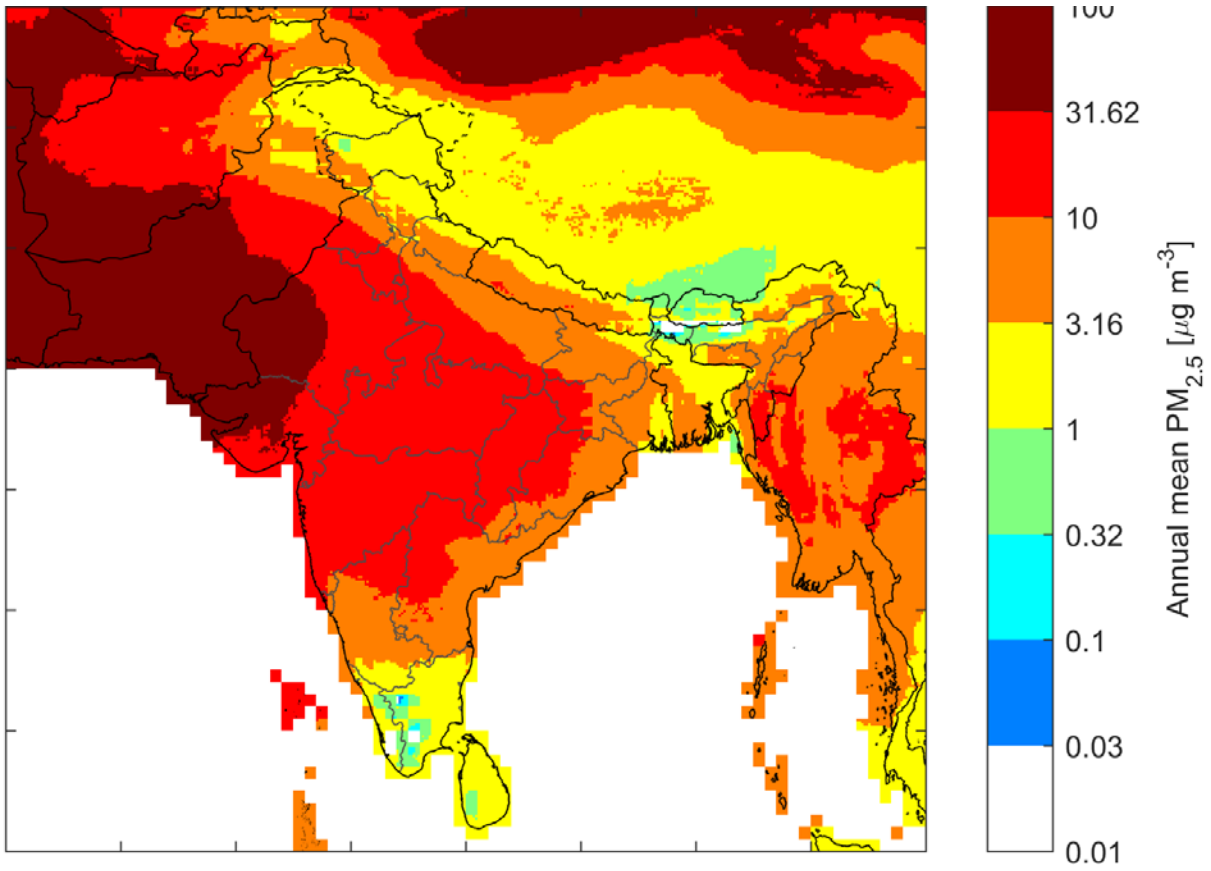
(examples for a few sectors…)

Computed $PM_{2.5}$ concentrations: Natural sources, 2015

Linear scale



Logarithmic scale

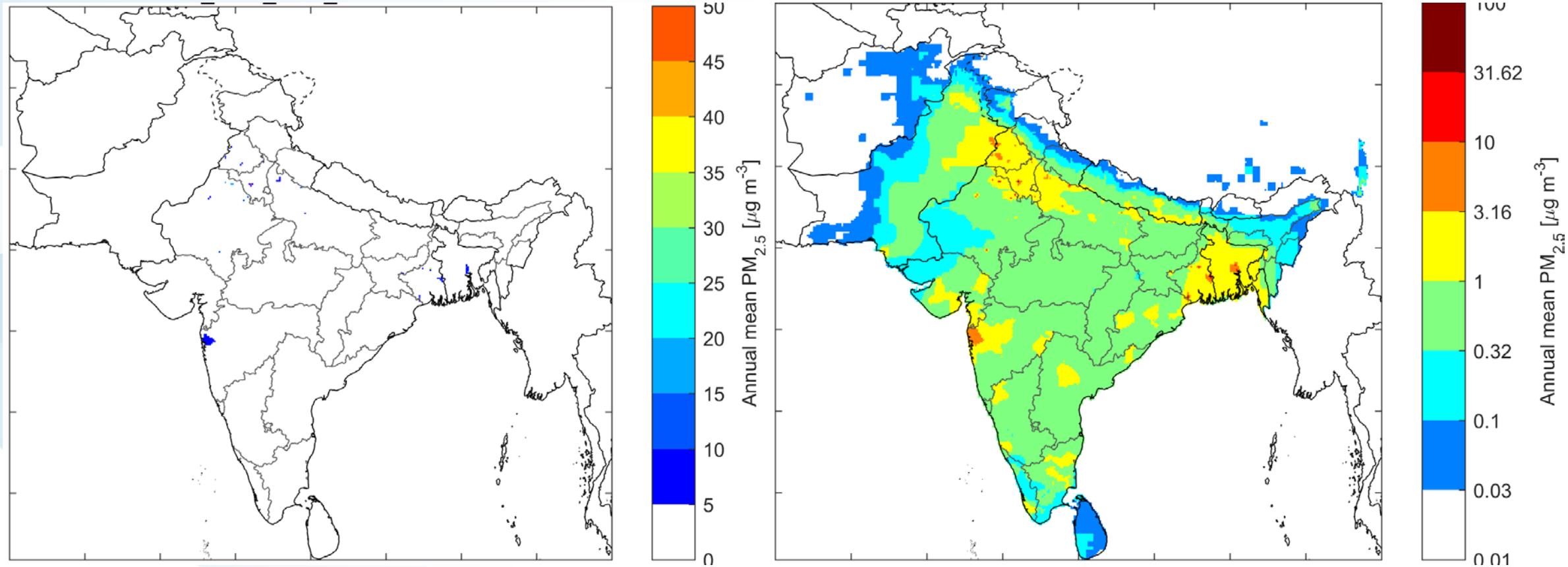


Preliminary results!

Computed $PM_{2.5}$ concentrations: Brick kilns, 2015

Linear scale

Logarithmic scale



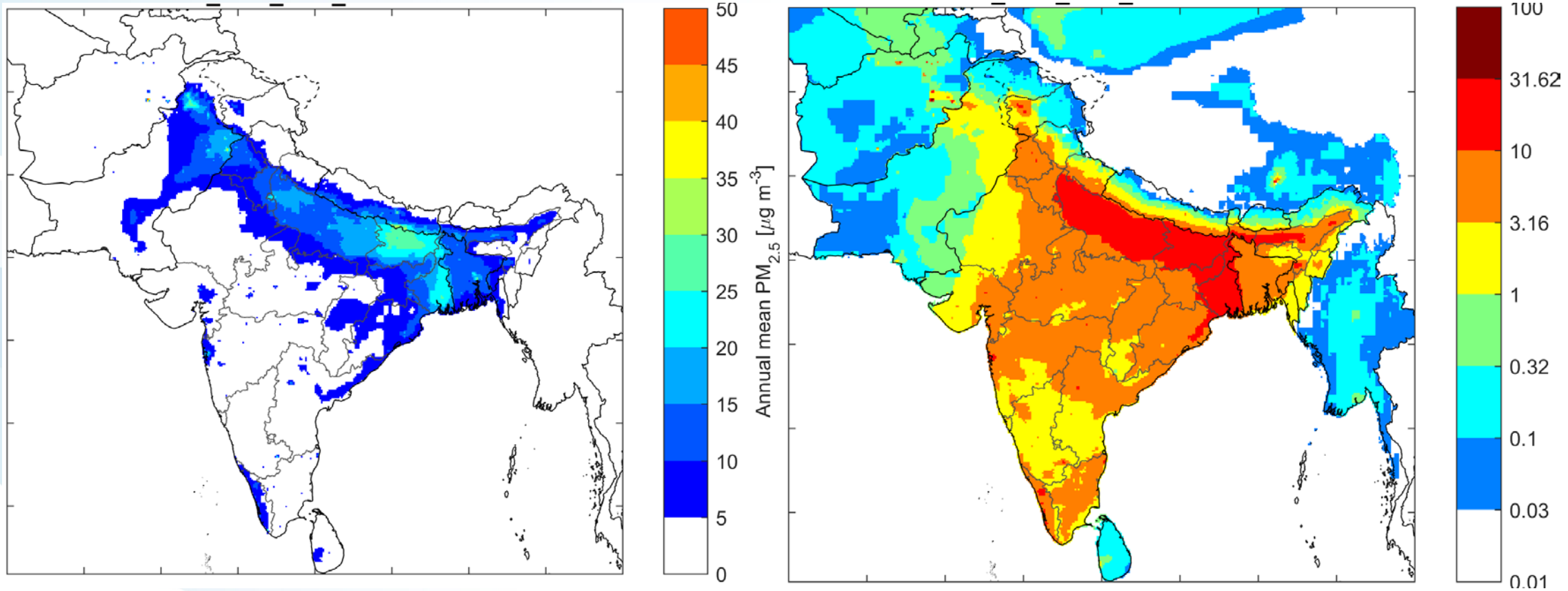
Mainly local contributions around brick production clusters in Northern states

Preliminary results!

Computed $PM_{2.5}$ concentrations: Residential & commercial, 2015

Linear scale

Logarithmic scale

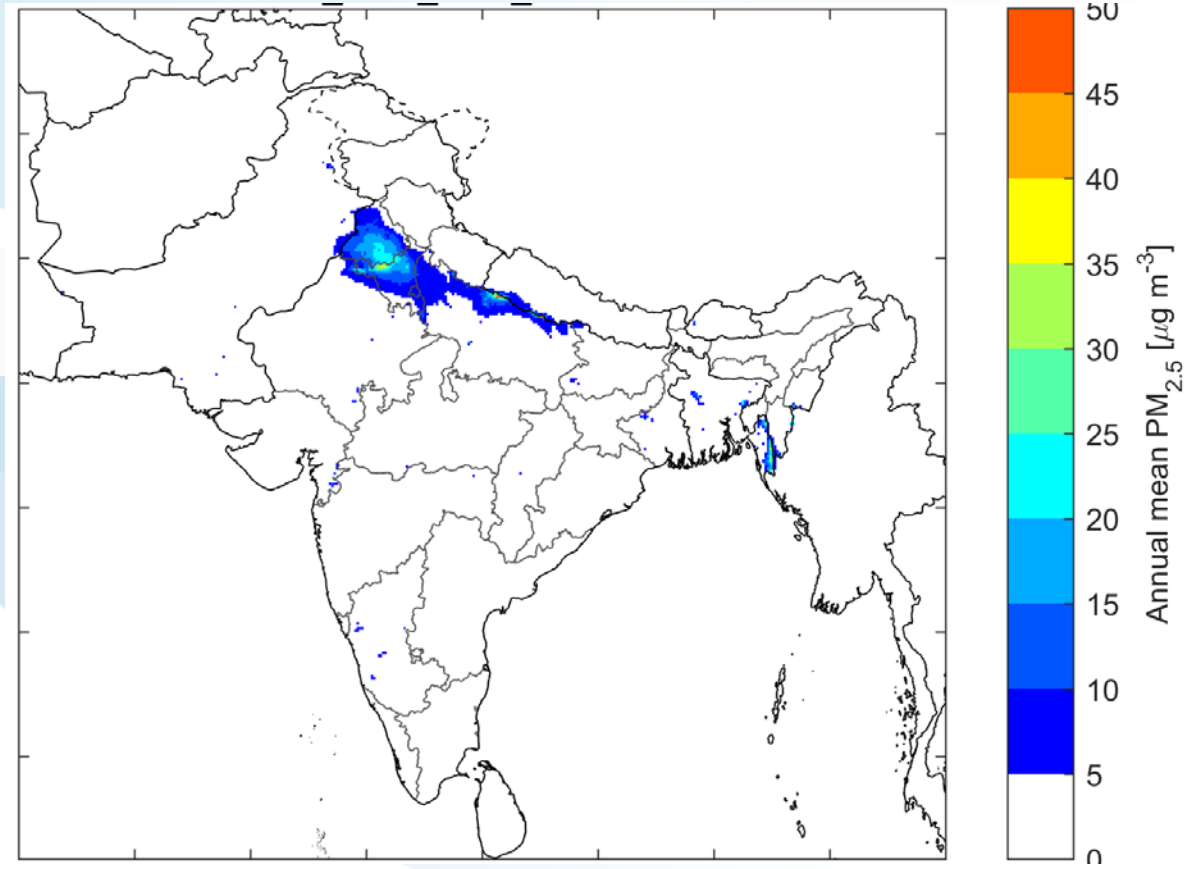


Mainly relevant in Gangetic Plain (Uttar Pradesh, Bihar…)

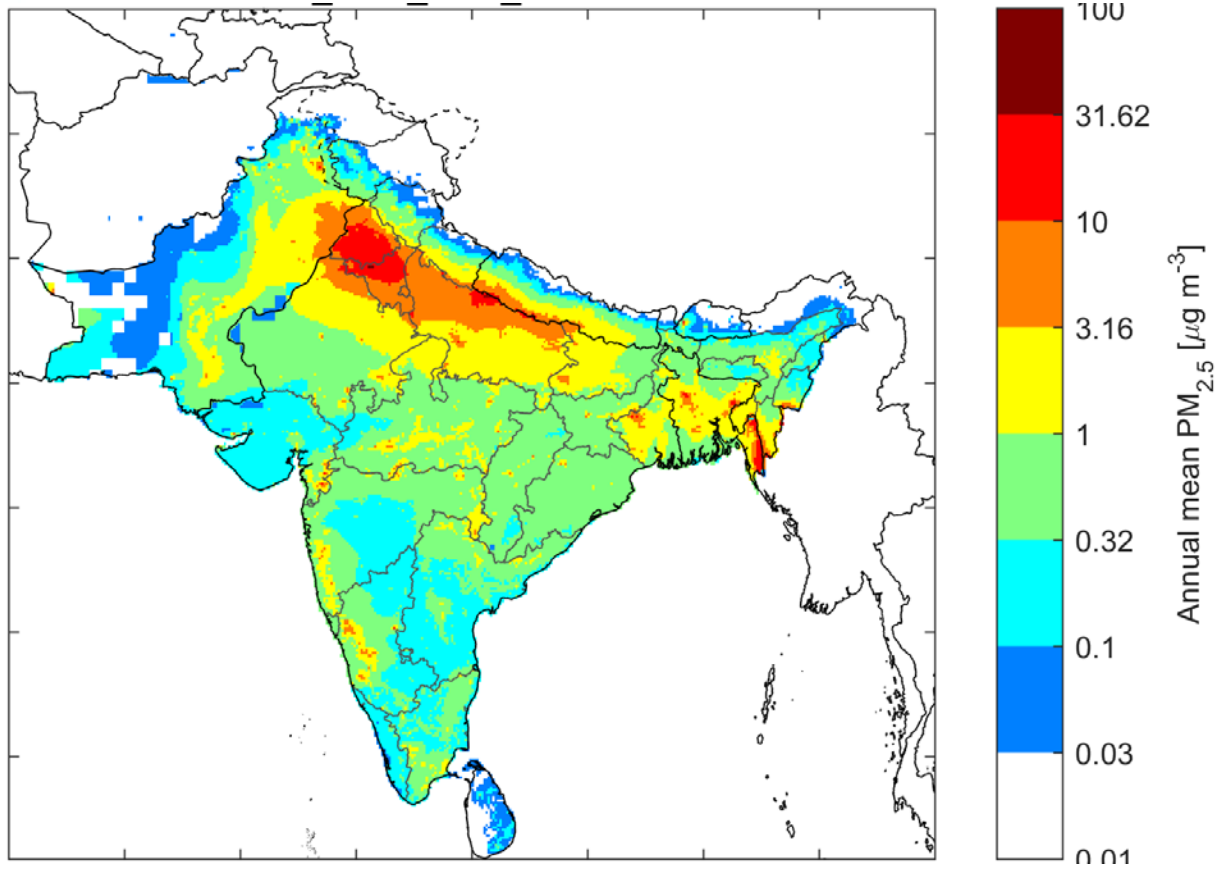
Preliminary results!

Computed $PM_{2.5}$ concentrations: Agricultural residue burning, 2015

Linear scale



Logarithmic scale

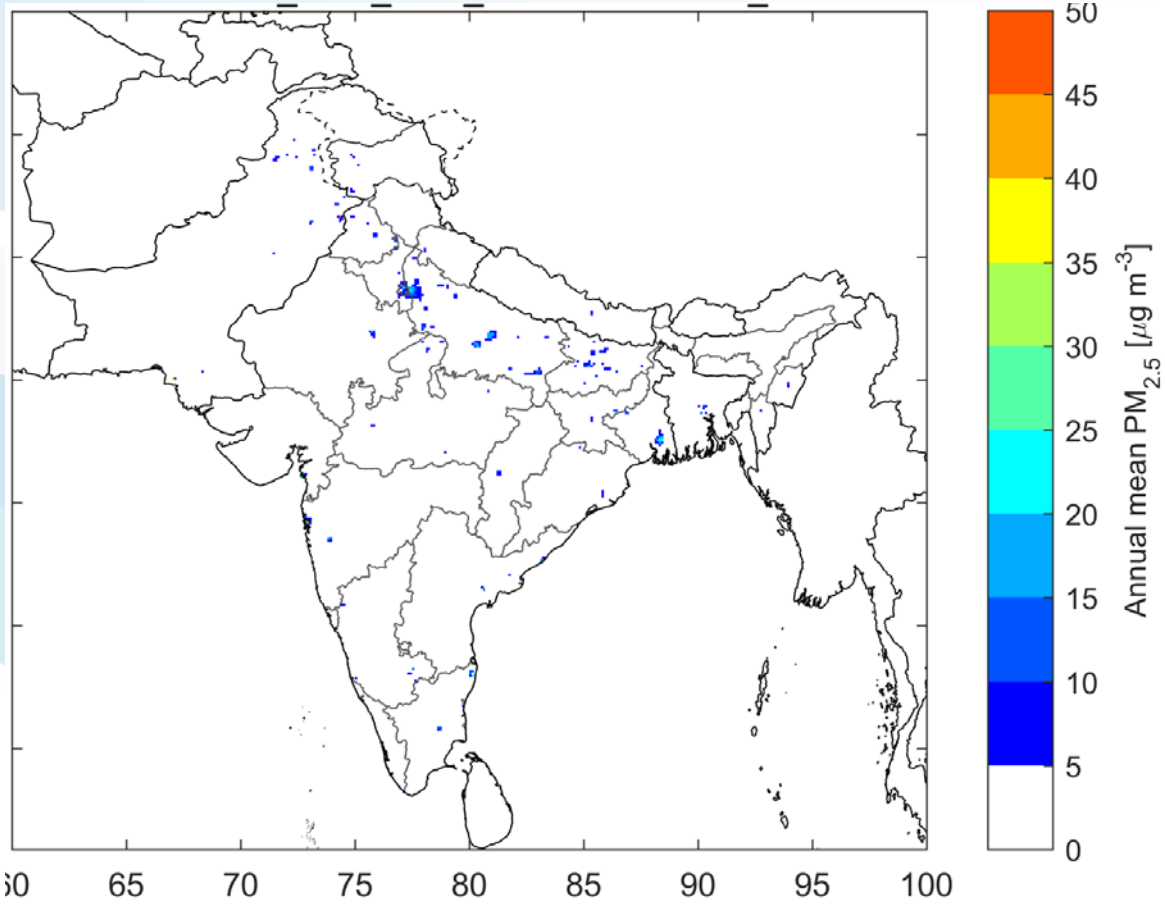


Mainly relevant in NW India, only during limited periods

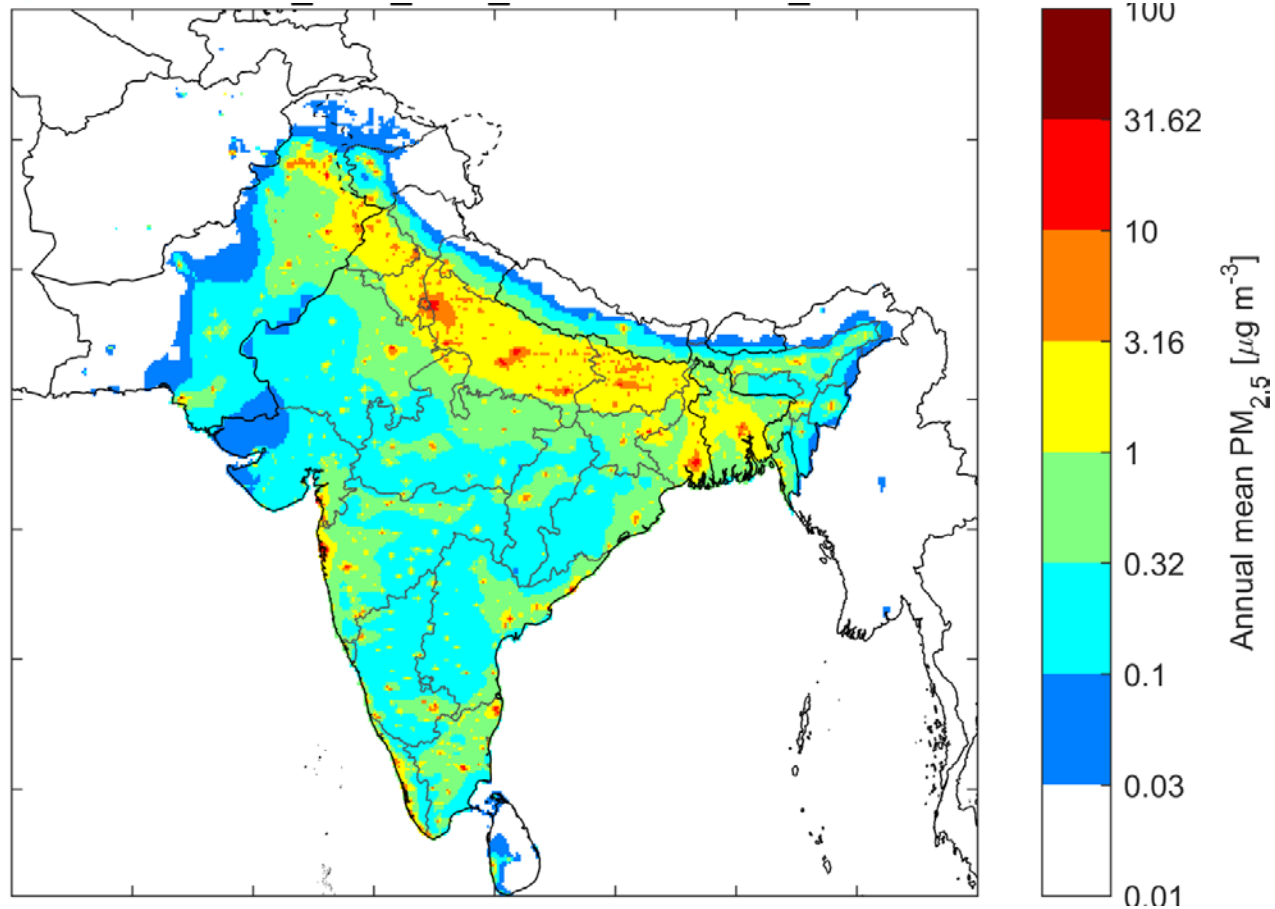
Preliminary results!

Computed $PM_{2.5}$ concentrations: Waste burning in cities, 2015

Linear scale



Logarithmic scale

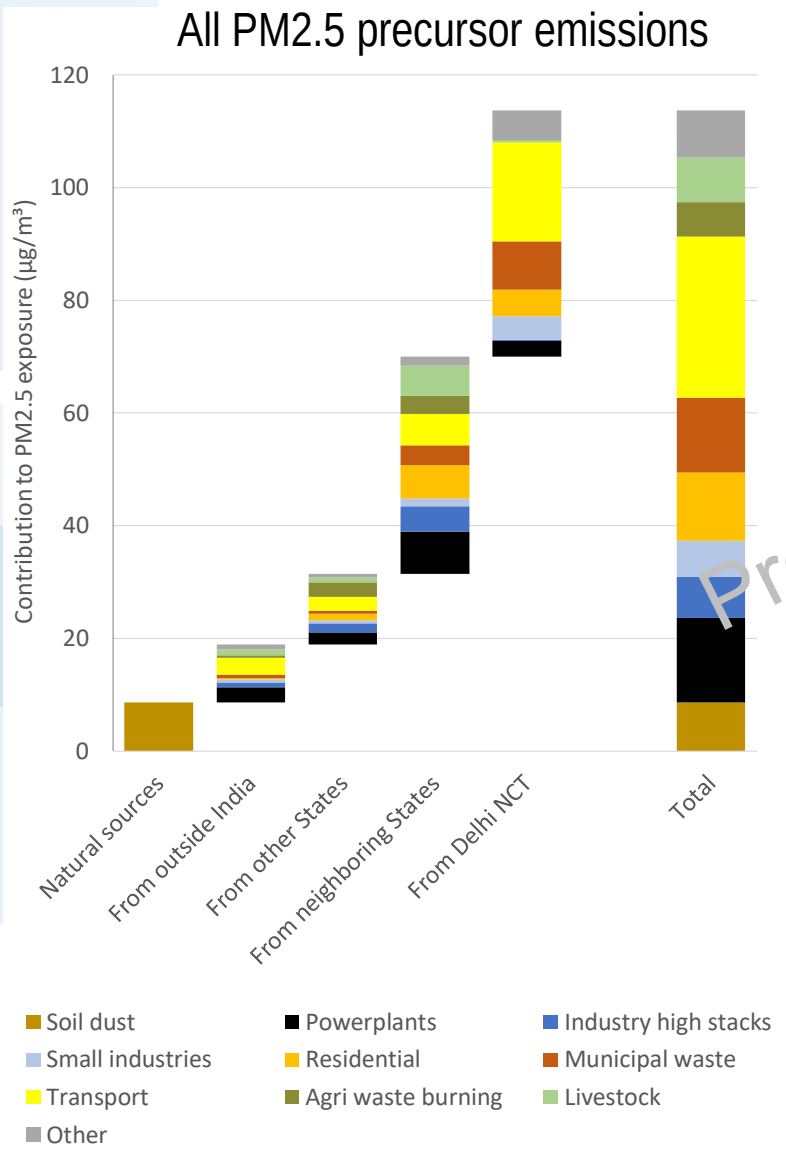


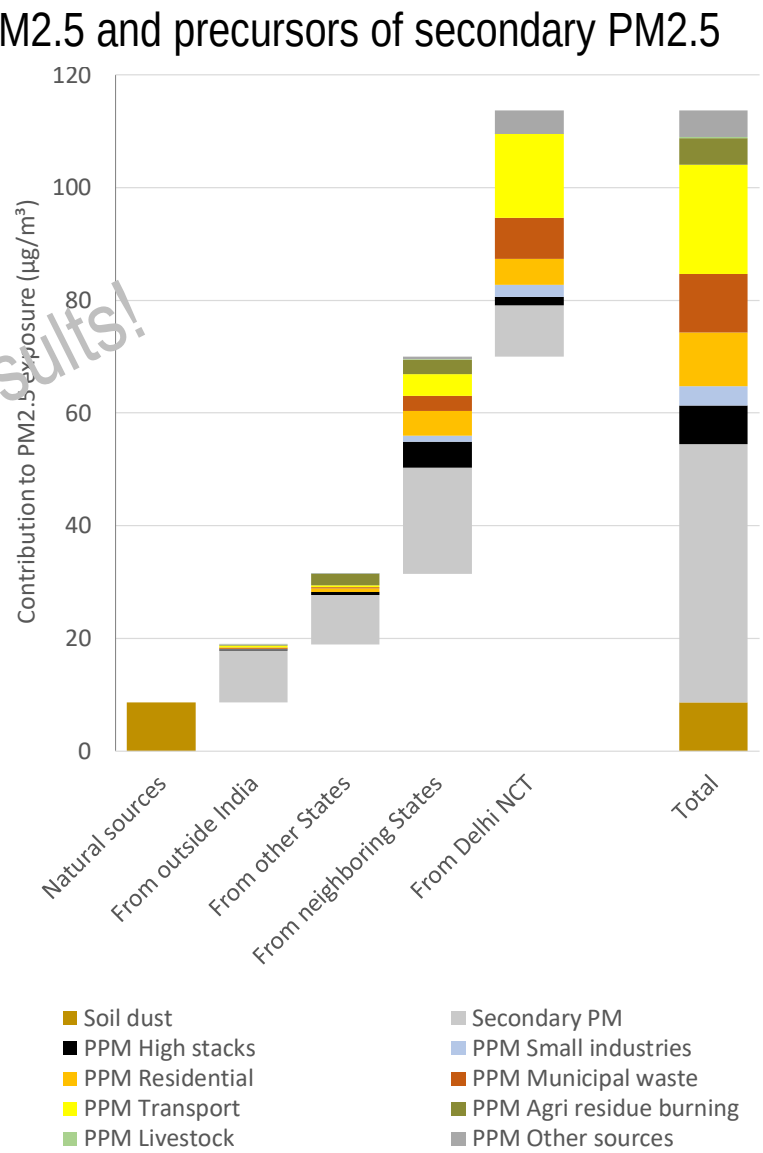
Significant local contributions…

Preliminary results!

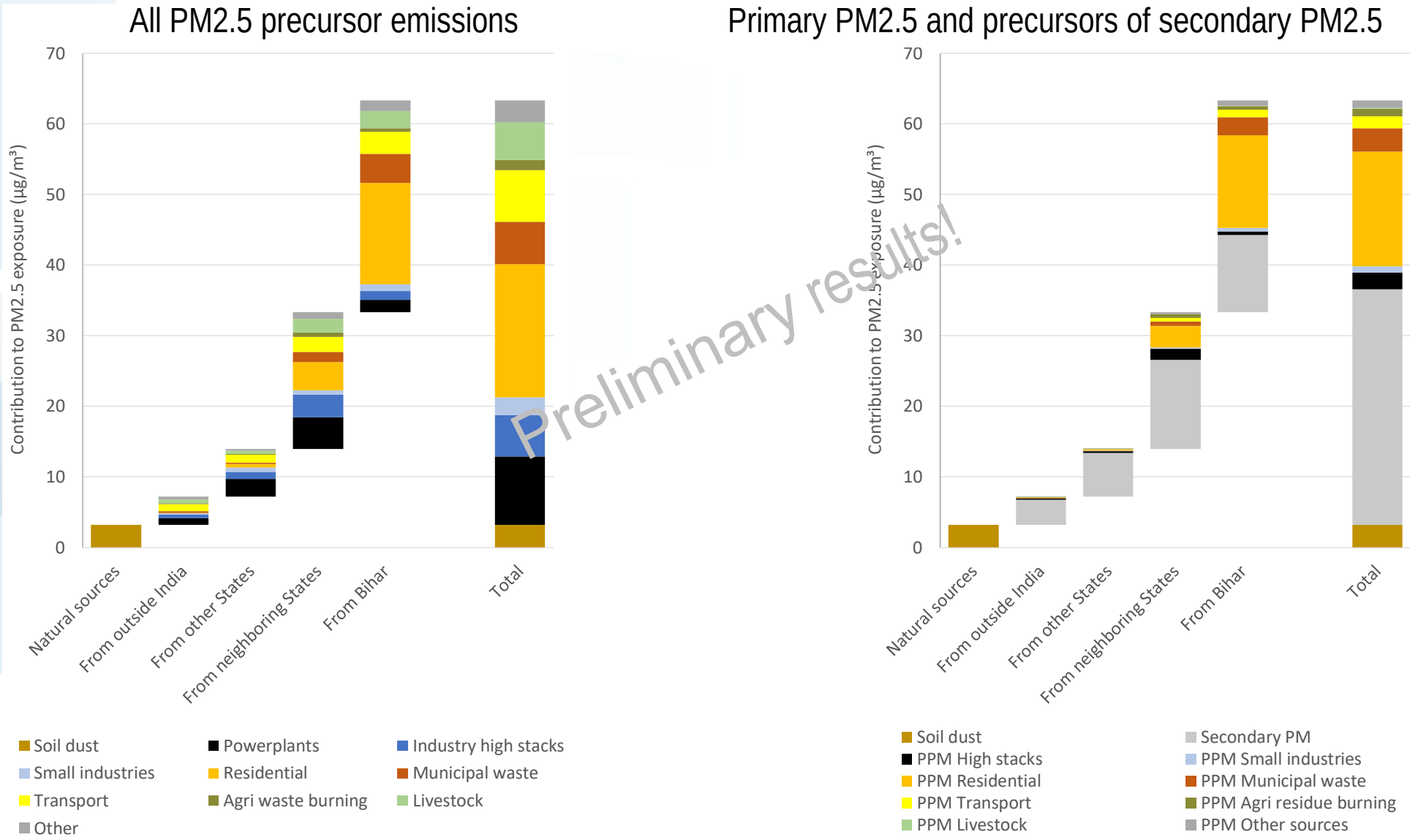
Contributions to $PM_{2.5}$ for Indian States (population-weighted)

Contributions to $PM_{2.5}$ exposure in Delhi NCT

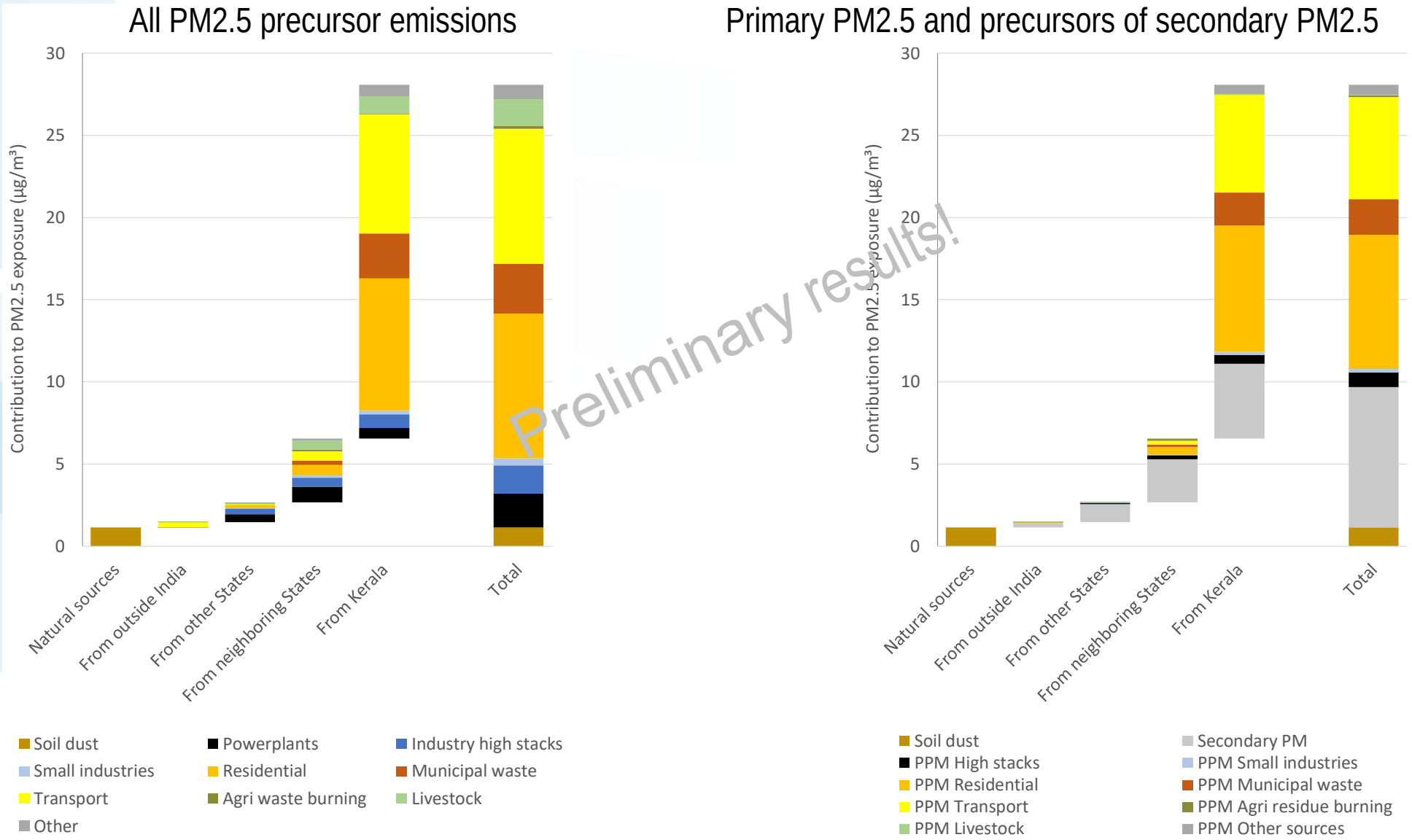




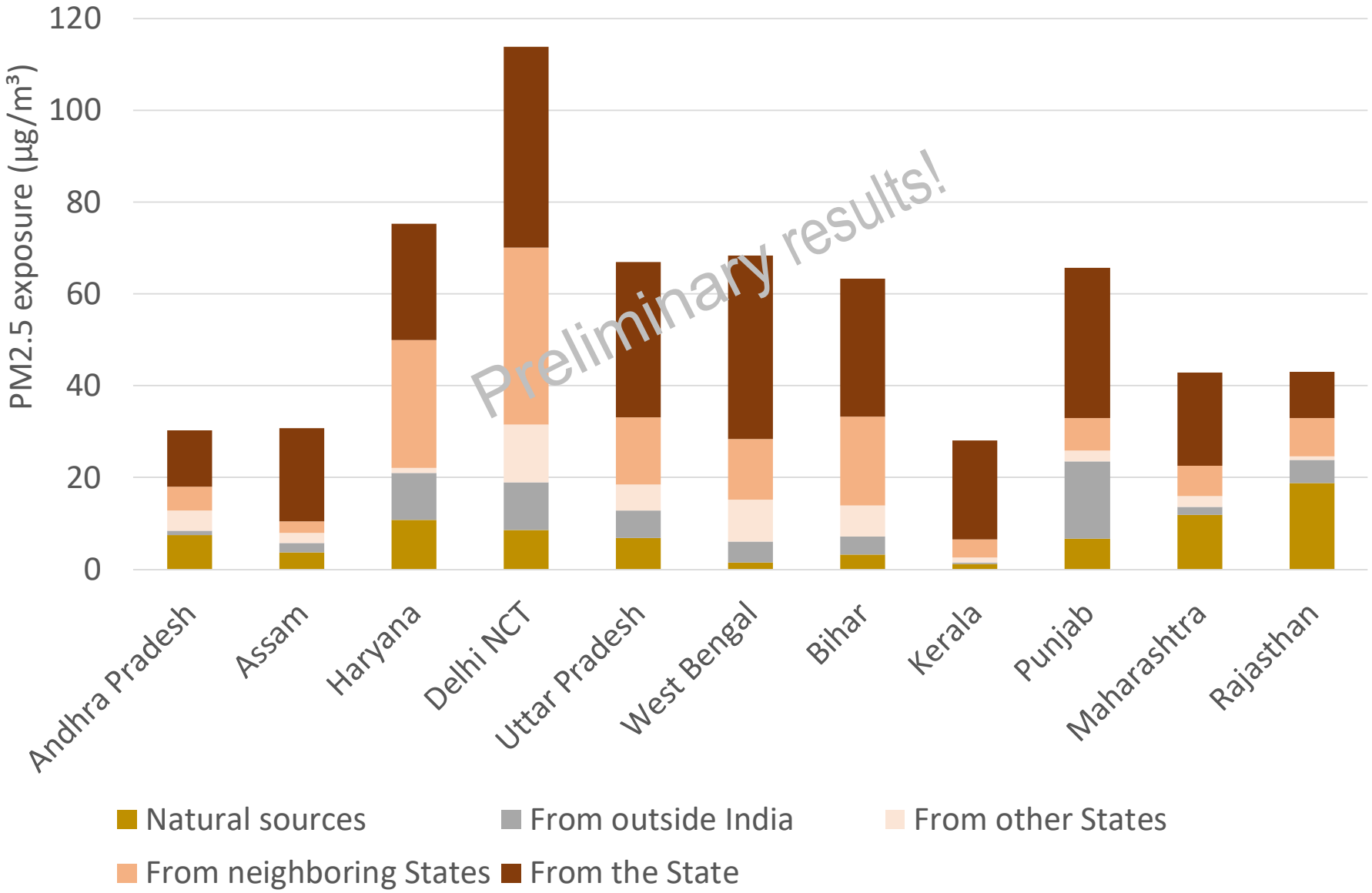
Contributions to $PM_{2.5}$ exposure in Bihar



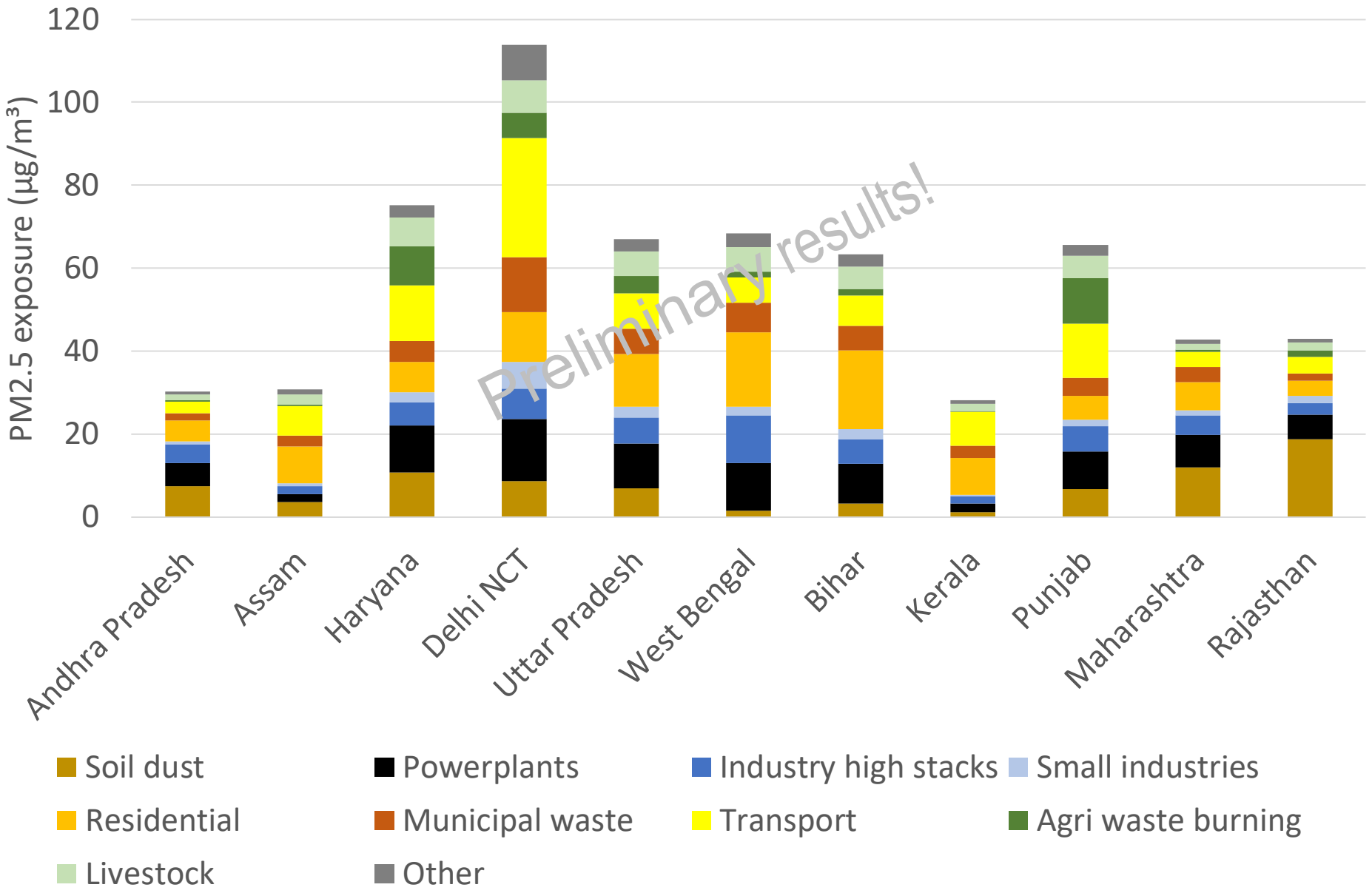
Contributions to $PM_{2.5}$ exposure in Kerala



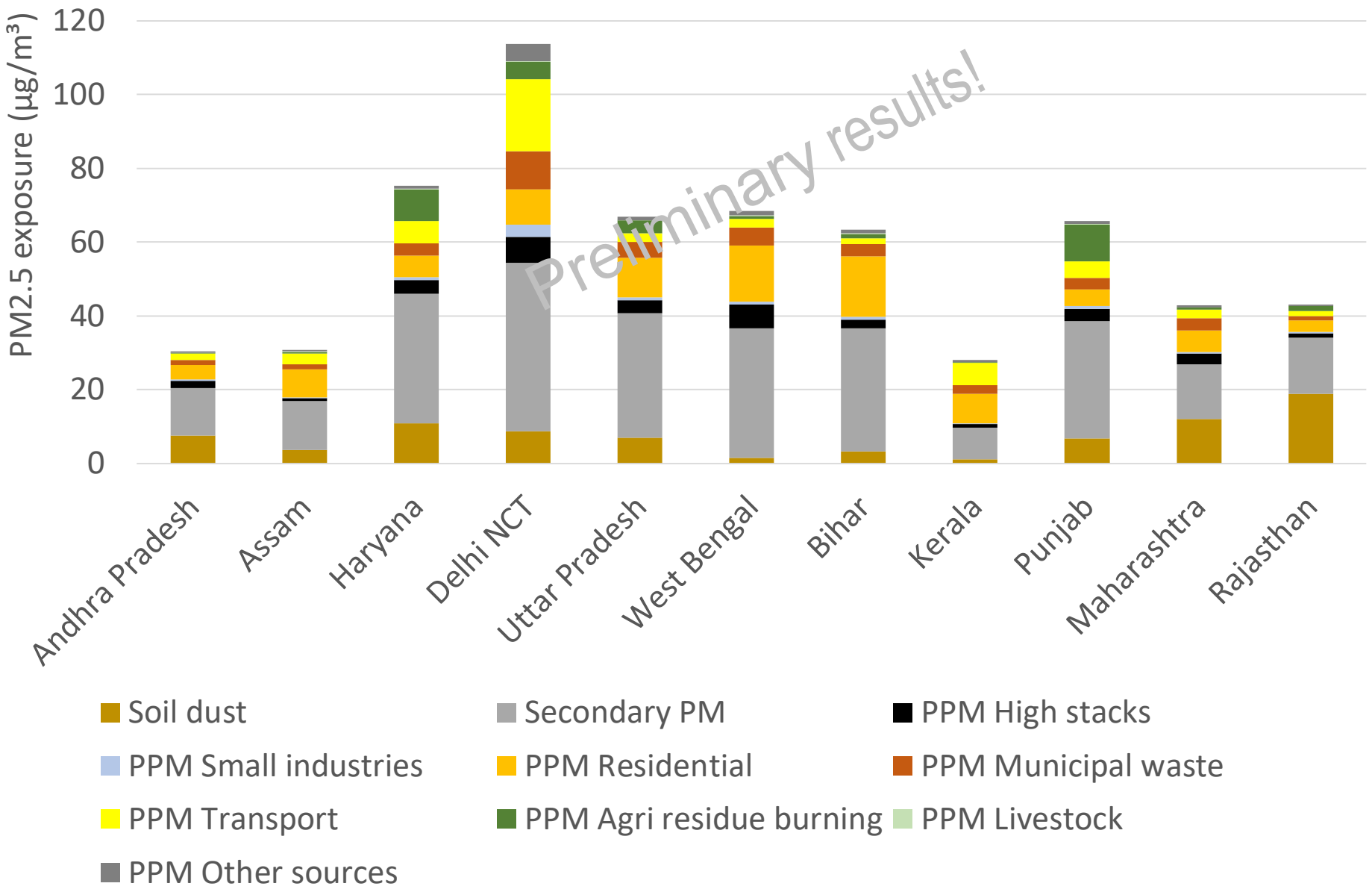
Spatial origin of $PM_{2.5}$ in Indian States, population-weighted



Sectoral origin of $PM_{2.5}$ in Indian States, population-weighted



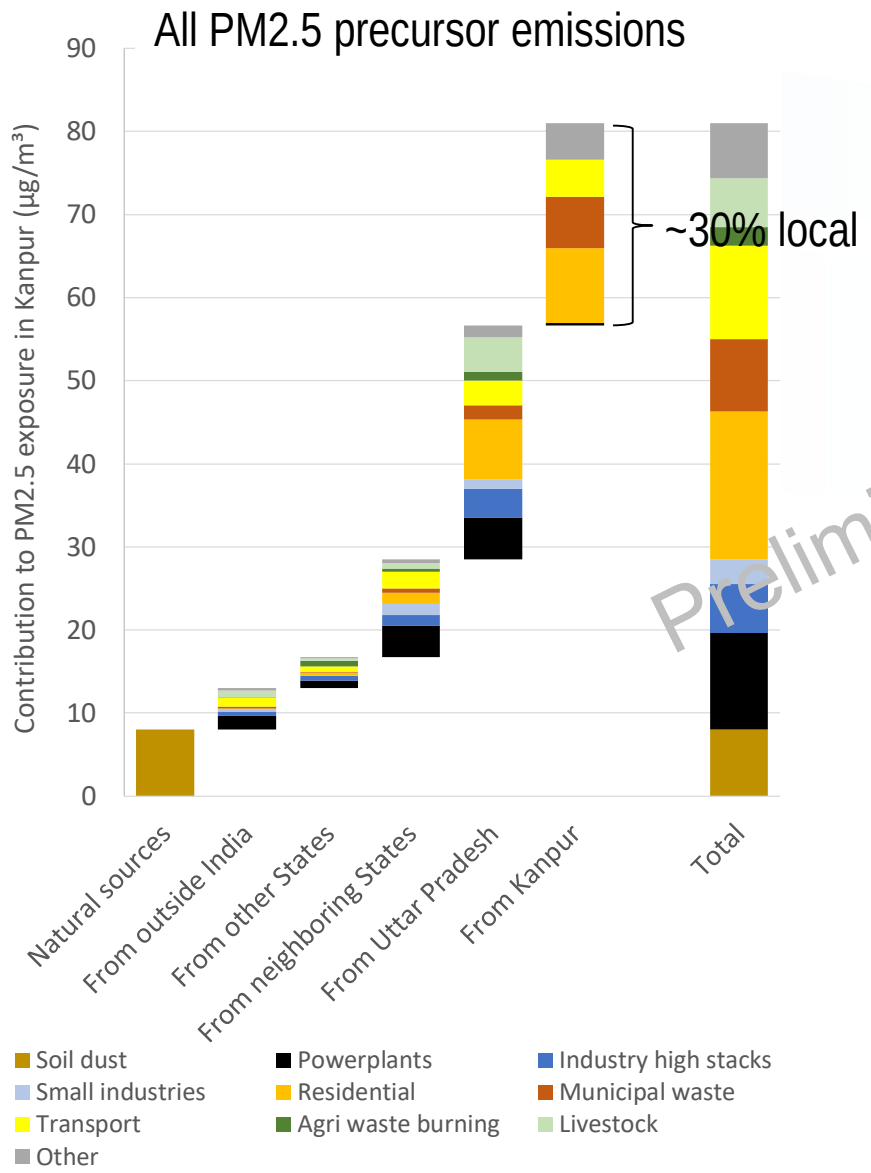
Primary/secondary $PM_{2.5}$ – States, population-weighted

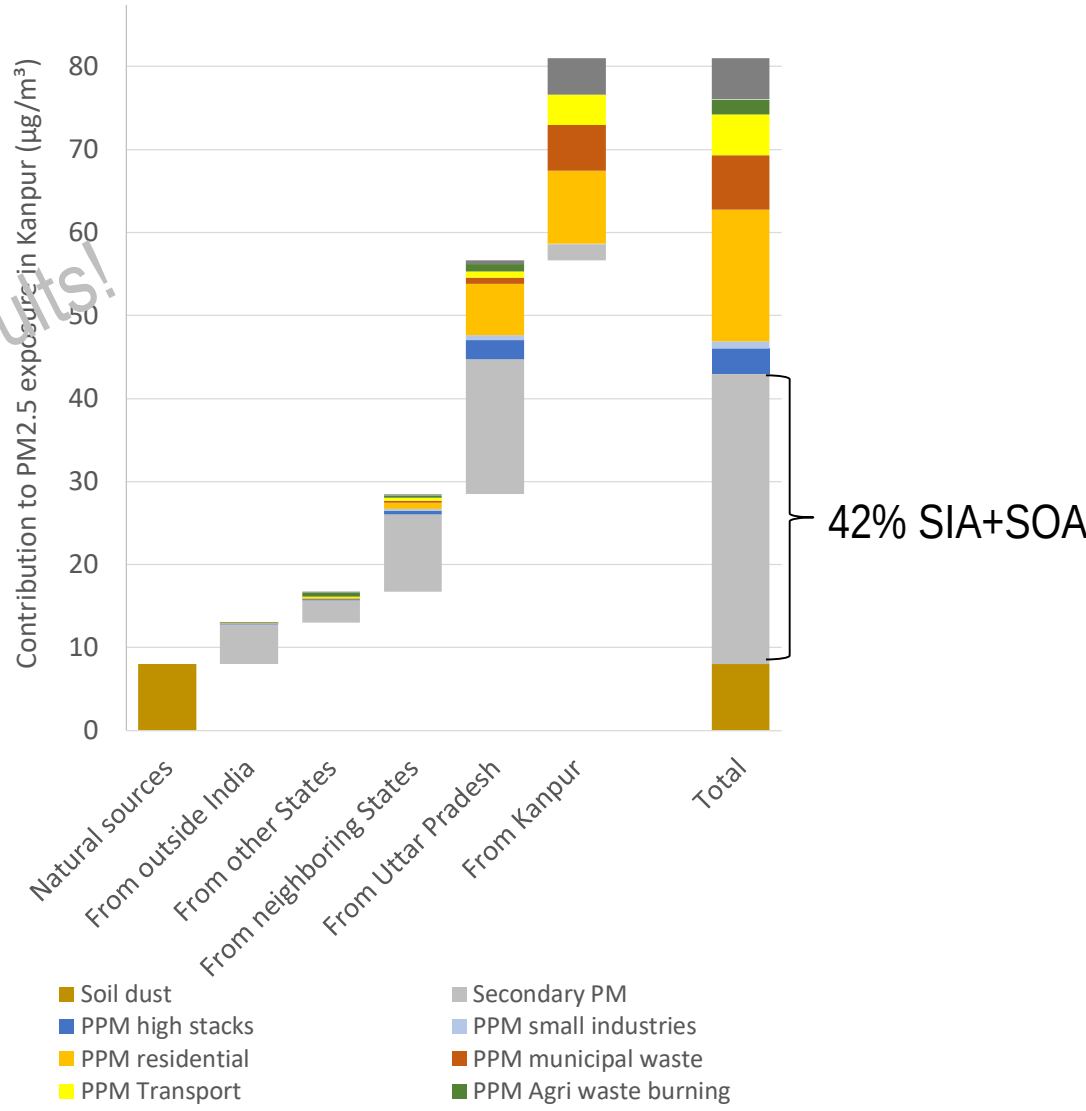


Contributions to $PM_{2.5}$ in cities

Some examples…

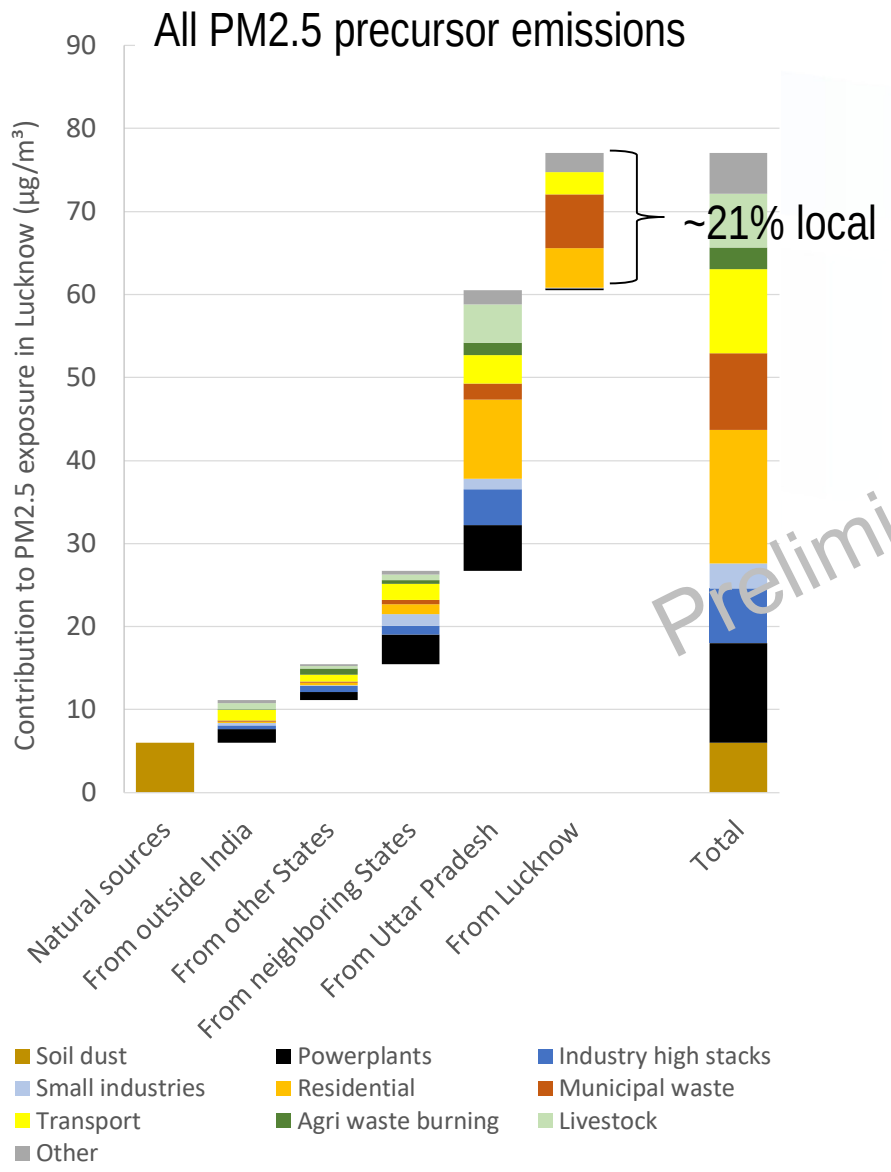
Contributions to $PM_{2.5}$ exposure in Kanpur

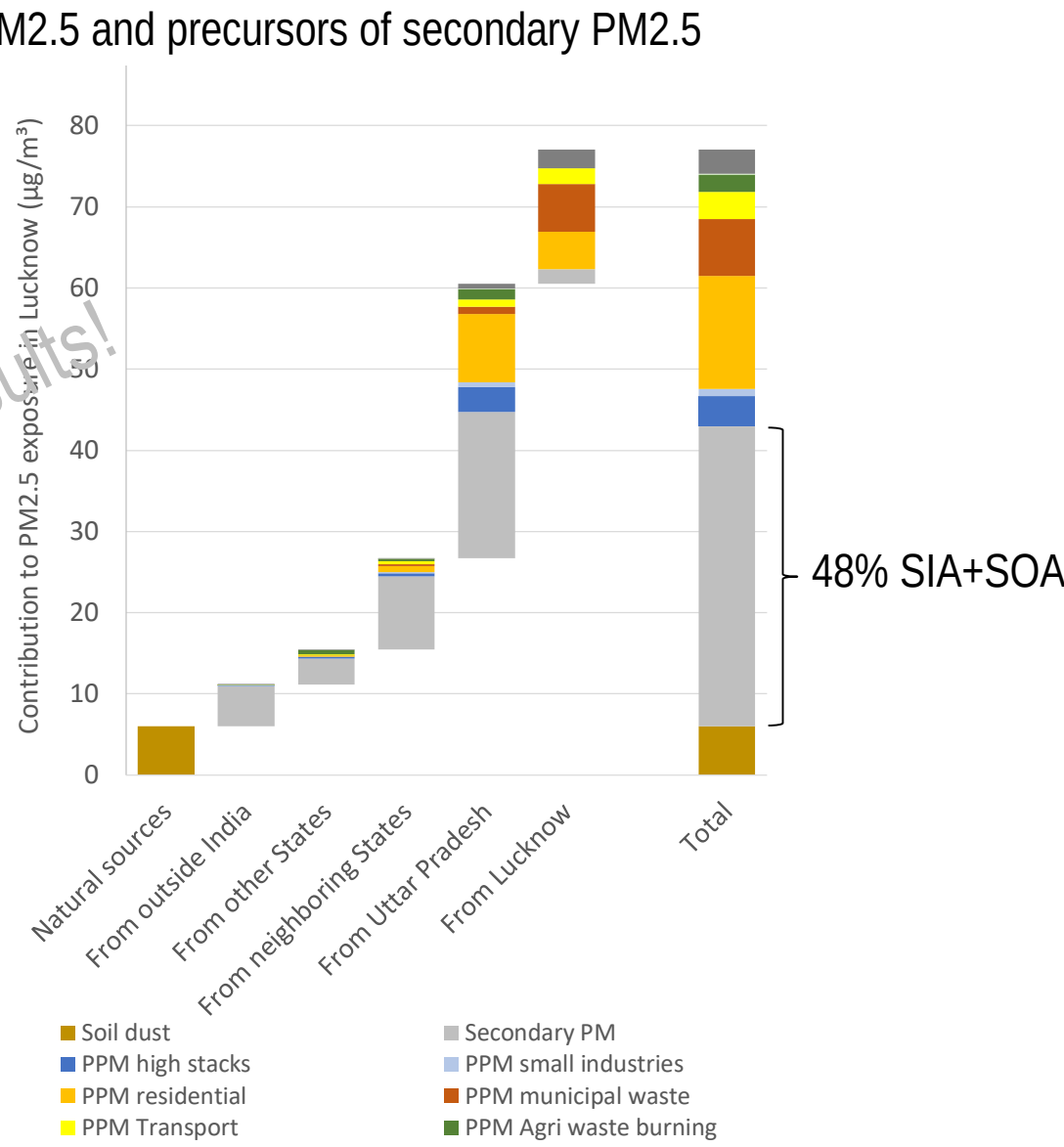




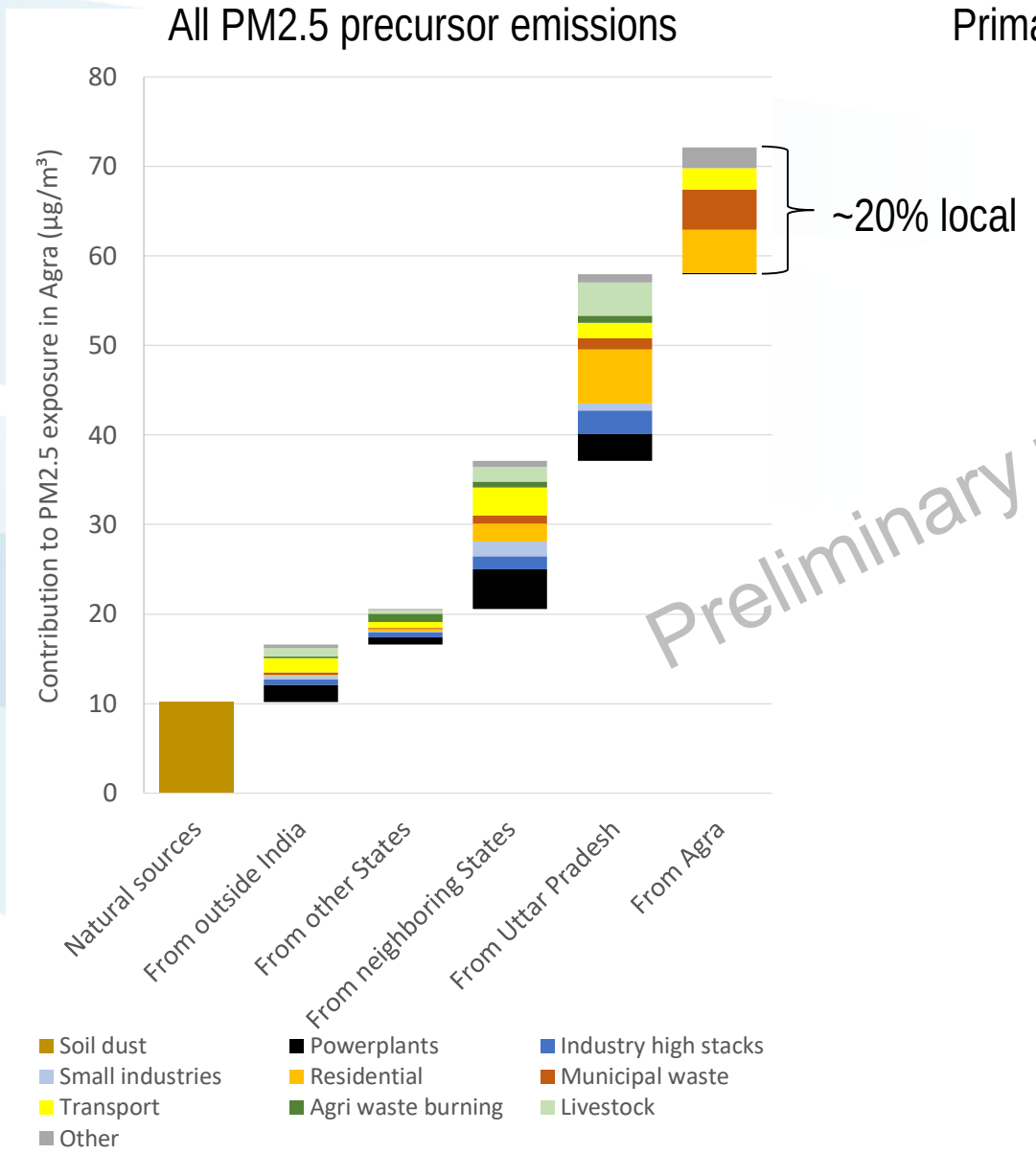
Preliminary results!

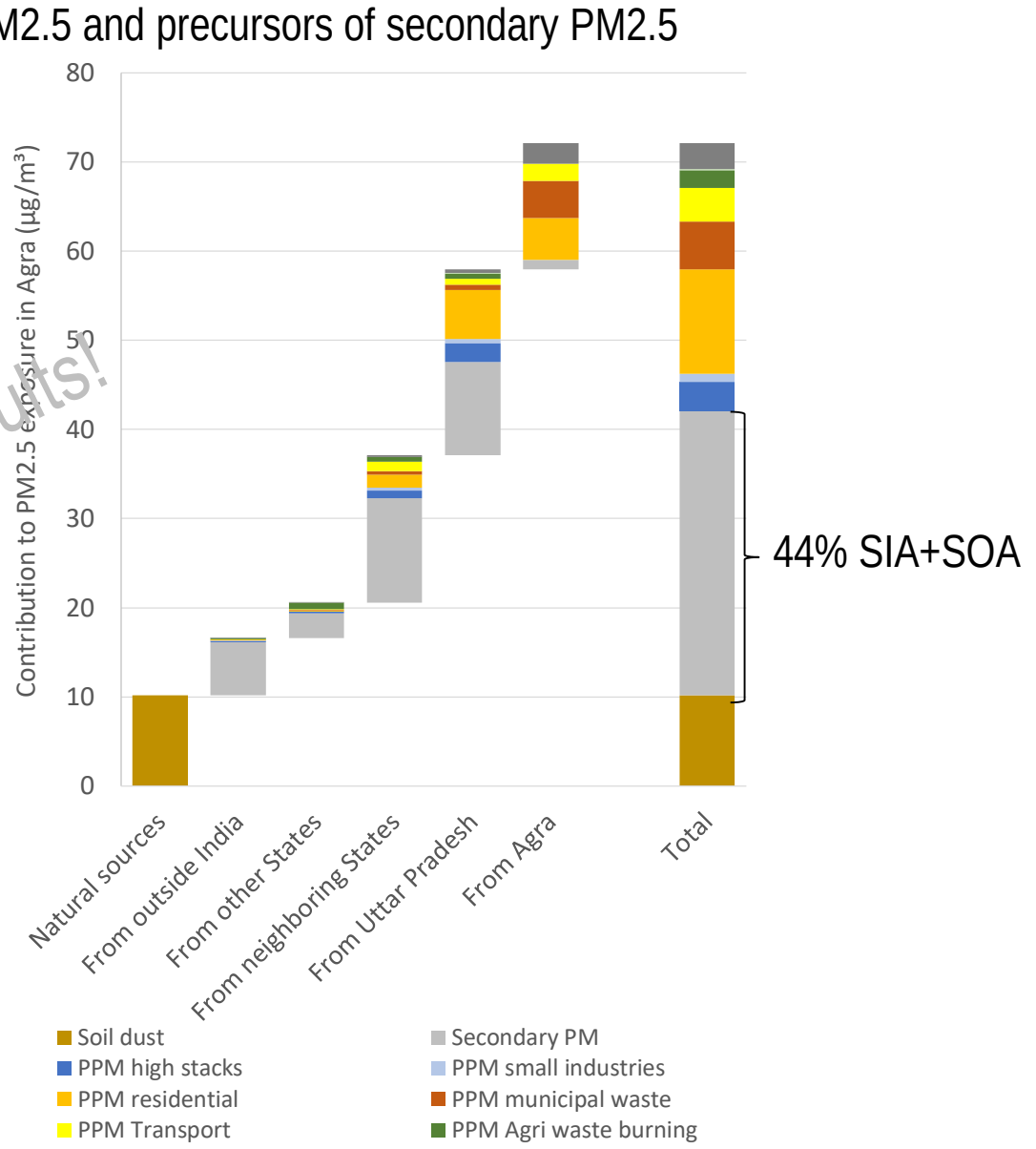
Contributions to $PM_{2.5}$ exposure in Lucknow





Contributions to $PM_{2.5}$ exposure in Agra





Preliminary results!

Some observations / (preliminary) conclusions

- Combination of traditional transfer coefficients with grid-to-grid tracking allows for improved ambient PM source apportionment in GAINS using sectoral transfer coefficients – work in progress…

- Importance of secondary $PM_{2.5}$ throughout India – a focus on the reduction of primary $PM_{2.5}$ will only address half of the problem.
  - Improved scientific understanding of the formation mechanisms/limitations of secondary $PM_{2.5}$ in India required
  - Improved emission inventories for NH_3 required.

- Clear evidence that cities cause only a limited share of their ambient $PM_{2.5}$ – implications for national clean air plans?

- The strong inter-State pollution transport in the Gangetic plain calls for an air shed AQM approach in this region. In other regions, there are strong linkages between cities and the surrounding State, but not so much across States.

Next steps

- Further refinement of source attributions for some sectors (brick kilns in Bangladesh, Nepal, household fuel use, port emissions in Bangladesh and Sri Lanka, etc.)
- Updates underway to base year 2018
- Tracking of PPM from other vertical layers – done from EMEP model side, not yet implemented
- Downscaling below 0.1º resolution / testing of uEMEP approach…
- Scenario analysis, demonstrating benefits of emission mitigation policies