India's Pathways to Reduce Air Pollution Exposure & Associated Health Burden: Policy Perspectives

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Acknowledgements: World Bank and SERB

5th ACAM Workshop, Dhaka, 8-10 June 2023

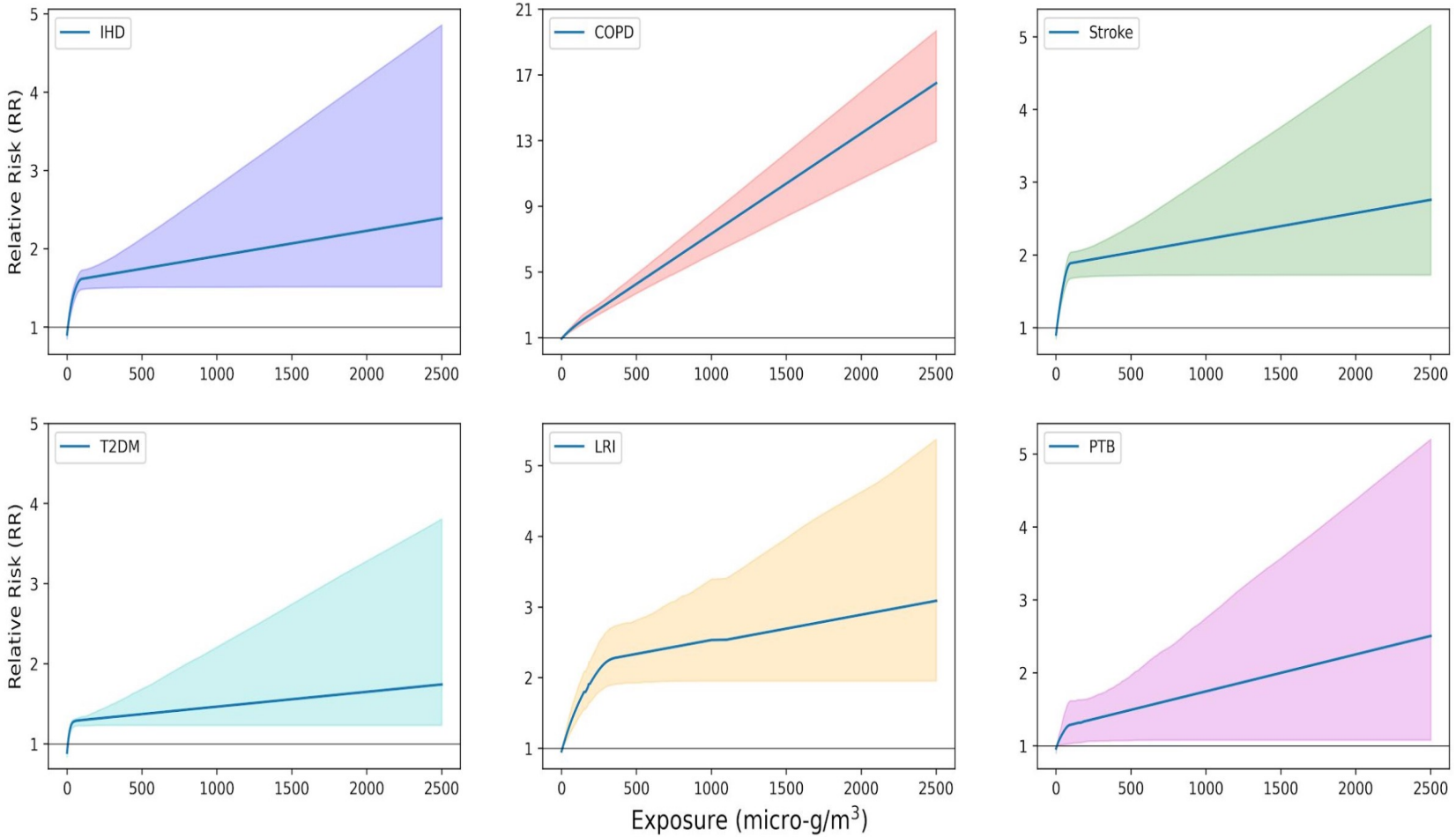
Global Burden of Disease Approach

$$\text{Burden} = (\text{BM} \times \text{Pop}) - \left(\frac{1}{RR} \times \text{BM} \times \text{Pop}\right)$$

Attributable to air pollution

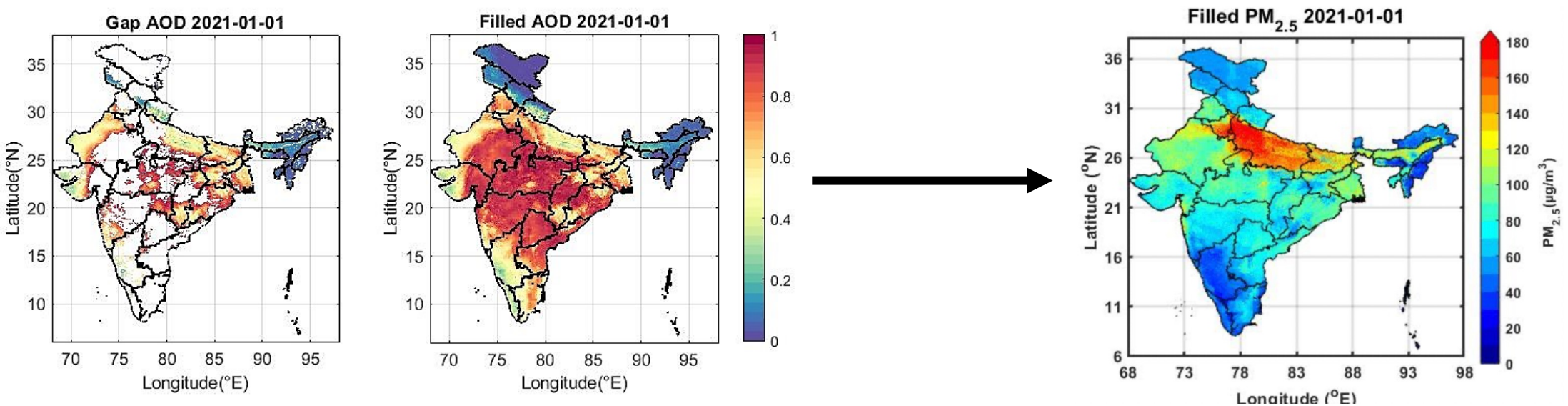
Total death of a disease

Total death of a disease apportioned to other risk factors

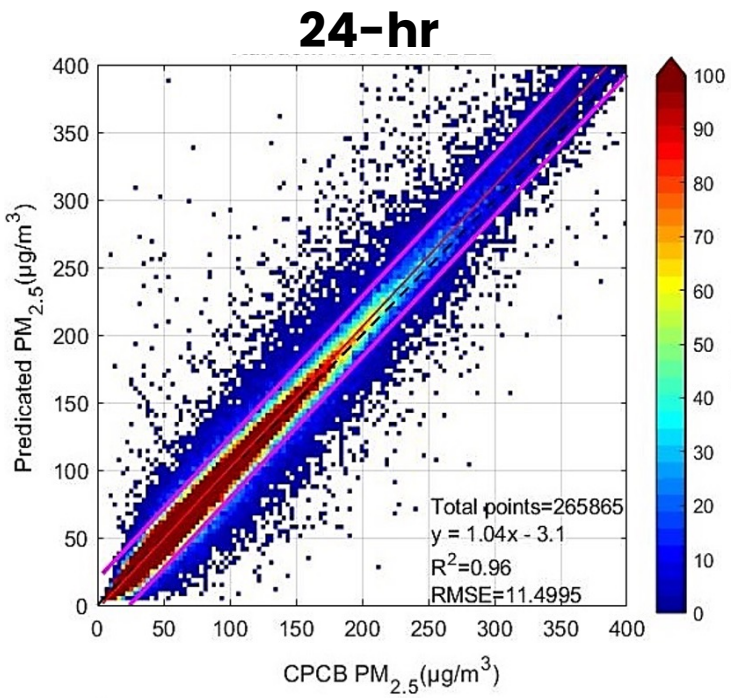


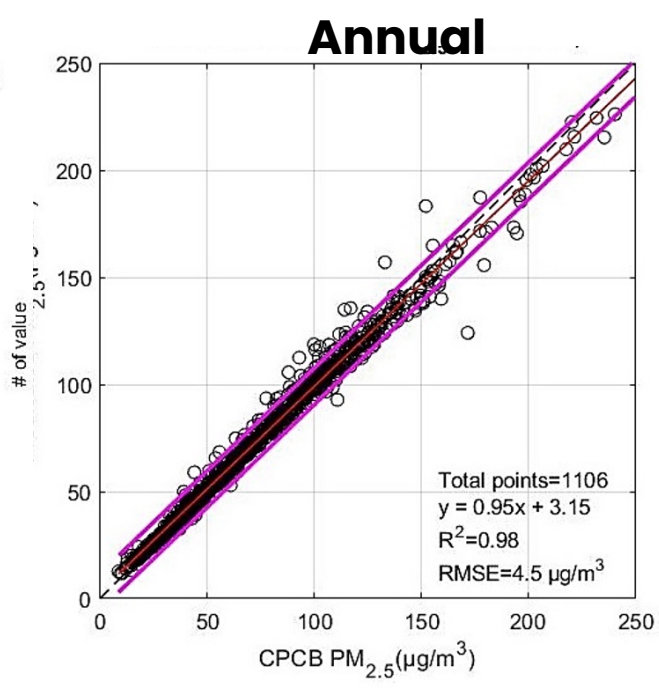
- Uniform approach to estimate mortality and morbidity burden of air pollution across the globes
- *RR* functions are developed for COPD, stroke, IHD, LRI, T2D and PTB
- State-level statistics are estimated for 1990 to 2019 [Balakrishnan et al., Lancet Planetary health, 2019; Pandey et al., lancet Planetary health, 2021]

Standardizing the algorithm for India

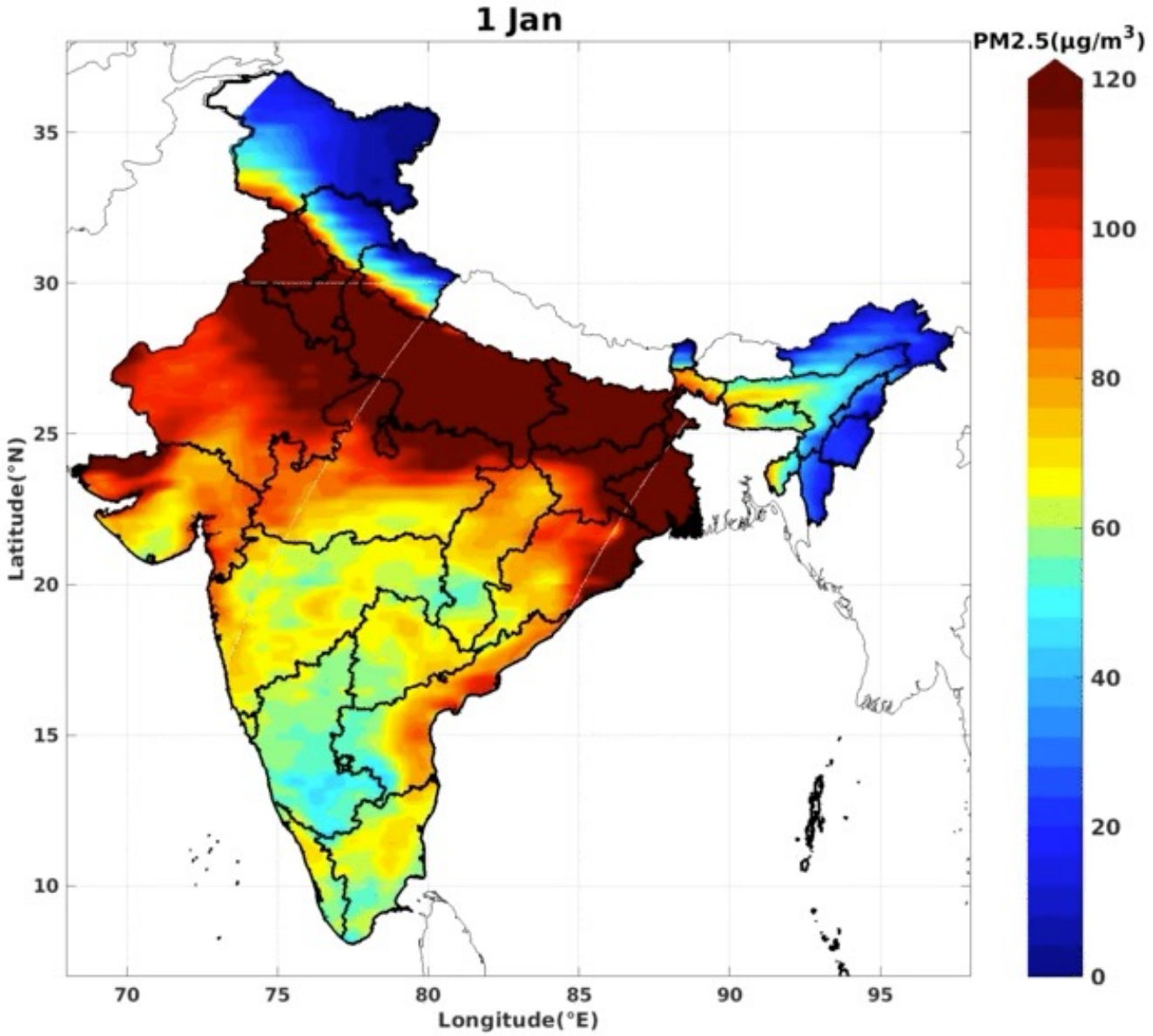


- Algorithm to convert AOD to surface $PM_{2.5}$ is standardized for India [Dey et al., 2012, 2020]
- $PM_{2.5}$ is retrieved at 1-km × 1-km spatial resolution from 2000 onwards
- Statistics has been generated at daily scale for 23+ years [Katoch et al., in review]





Pollution Cycle in India



- Air pollution in South Asia is a regional & year-round problem
- Major aerosol species is different depending on the season and local emission characteristics
- Eastern Indian states and Bangladesh receive the IGP outflow for most of the months

Approach to Prioritize Sectoral Interventions

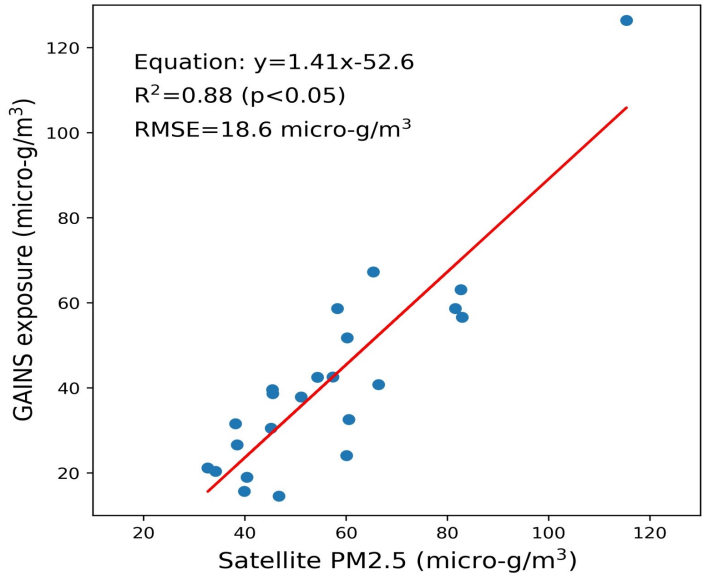
Activity → **GAINS** → **Emission** → **$PM_{2.5}$**

$$E_{i,p} = k\ m\ A_{i,k}\ e_{i,k,m,p} X_{i,k,m,p}$$

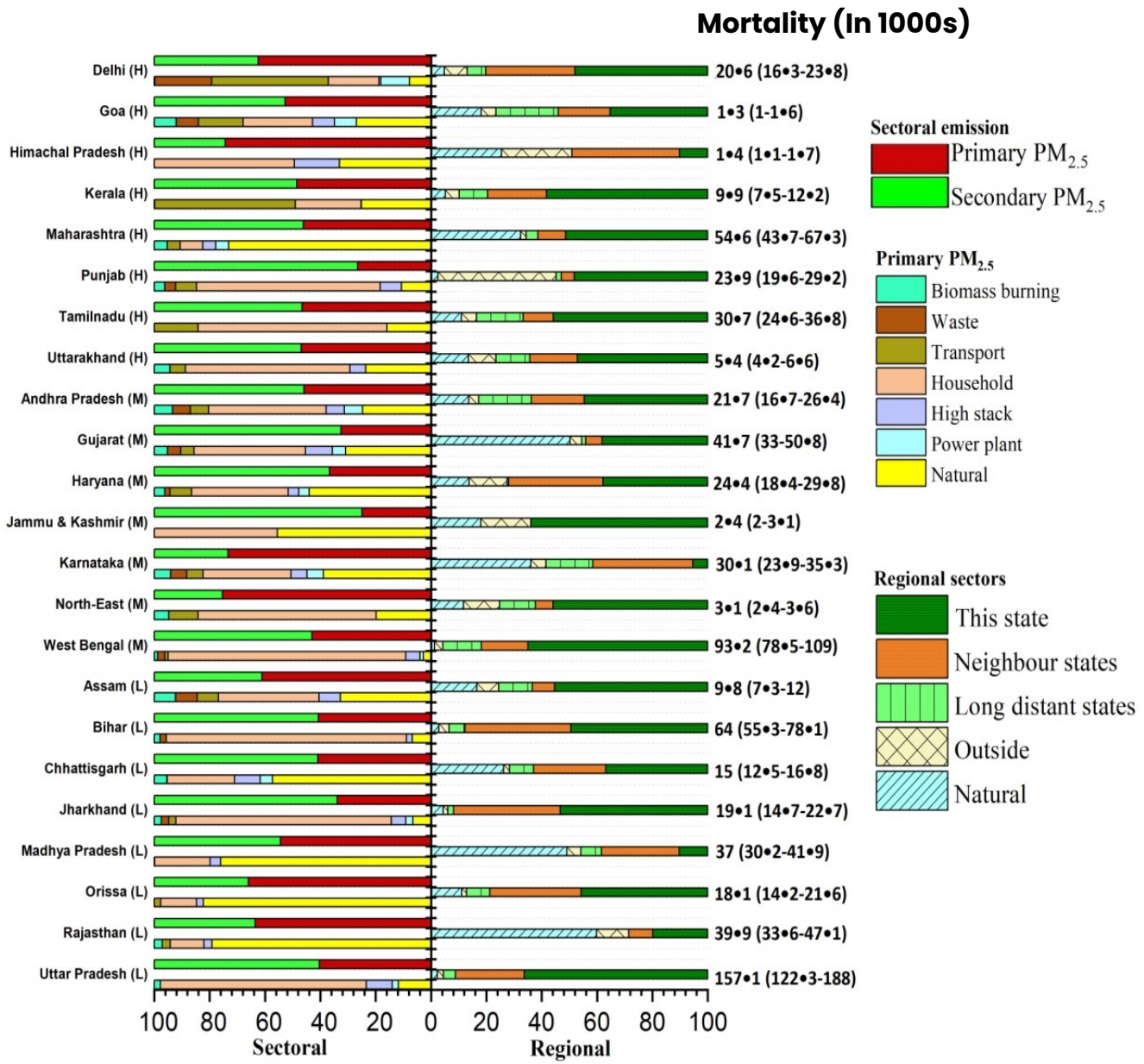
- $E_{i,p}$: location, pollutant
- k: activity level
- m: activity type
- $A_{i,k}$: activity level
- $e_{i,k,m,p}$: emission factor
- $X_{i,k,m,p}$: share of control, Control measure

[Amann et al., 2011]

- GAINS is a reduced complexity model
- Sectoral and regional contributions for
  - 2015 baseline [Purohit et al., 2019]
  - 2030 in BAU, ACT and SDS pathways
- For future, population and baseline mortality projection from Indian census and past trend (1990-2019)



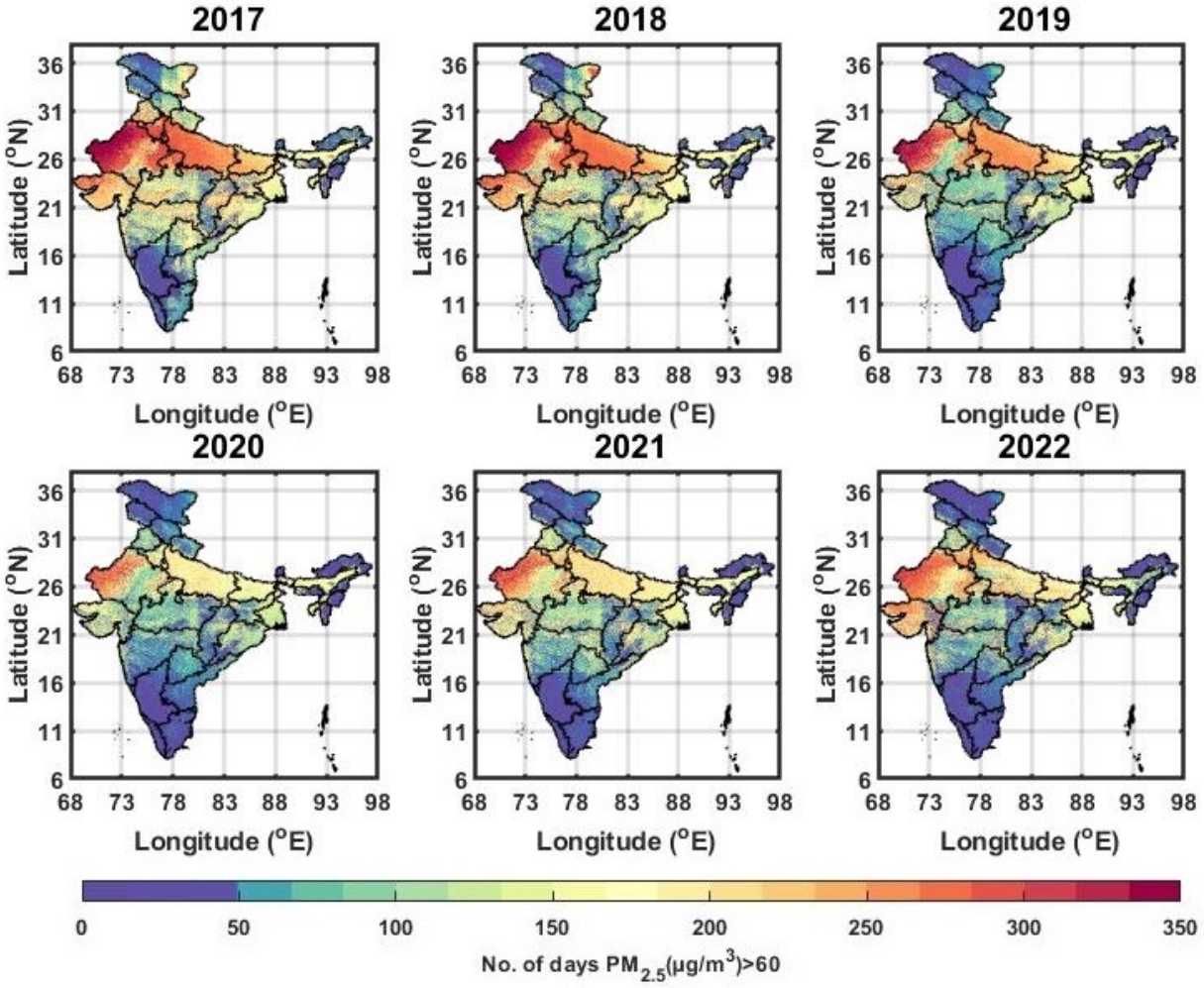
Burden apportionment



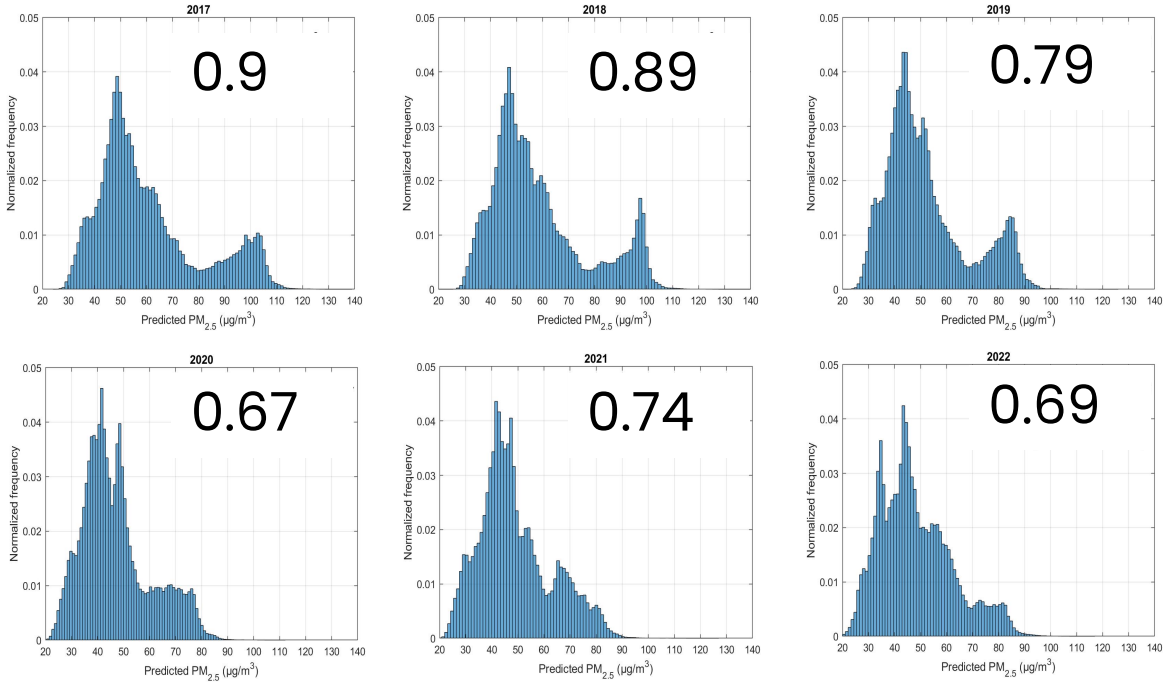
- Secondary $PM_{2.5}$ dominates over primary $PM_{2.5}$ - Controlling precursor gases is equally important
- Domestic shows the highest contributions to primary $PM_{2.5}$
- Regional cooperation is key for accelerated progress
- For border states in India, international cooperation is critical

[Sarkar et al., *in preparation*]

$PM_{2.5}$ exposure in the NCAP era

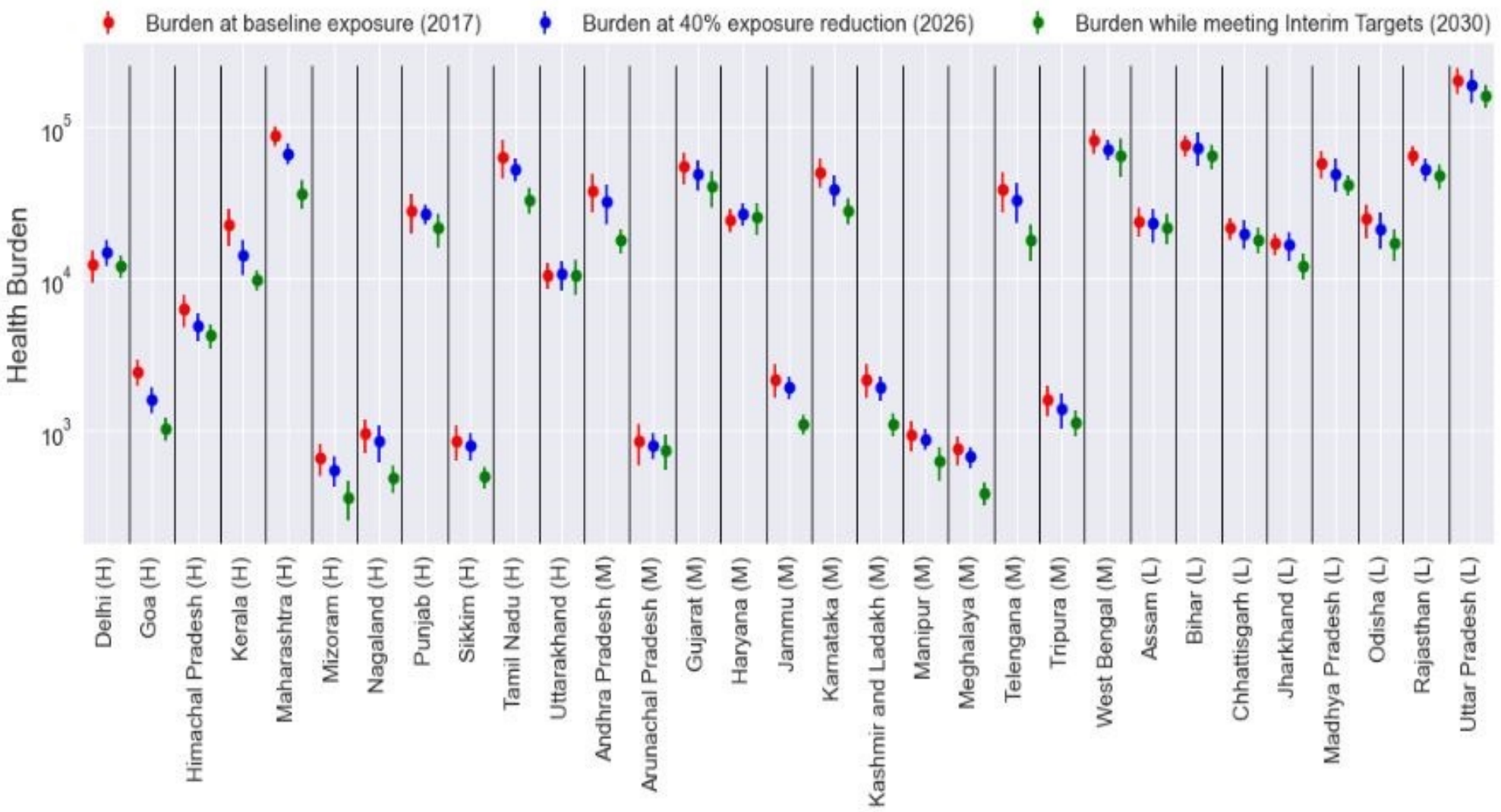


f_{grids} > NAAQS in recent years



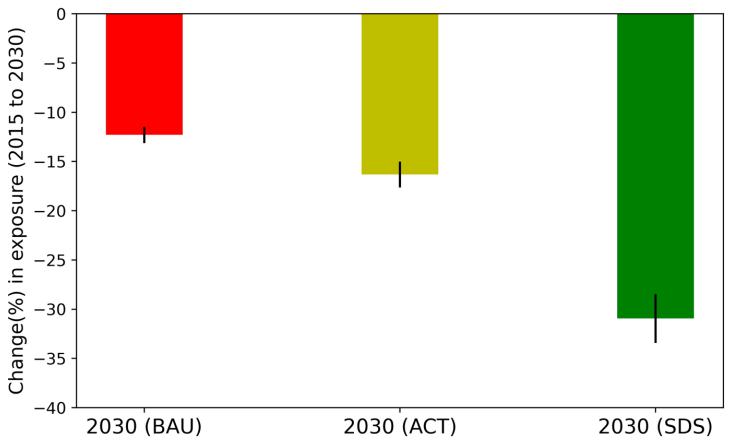
References: Dey et al., 2020; Katoch et al., in review [see SAANS portal www.saans.co.in for more details]

Expected health benefits of cleaning air

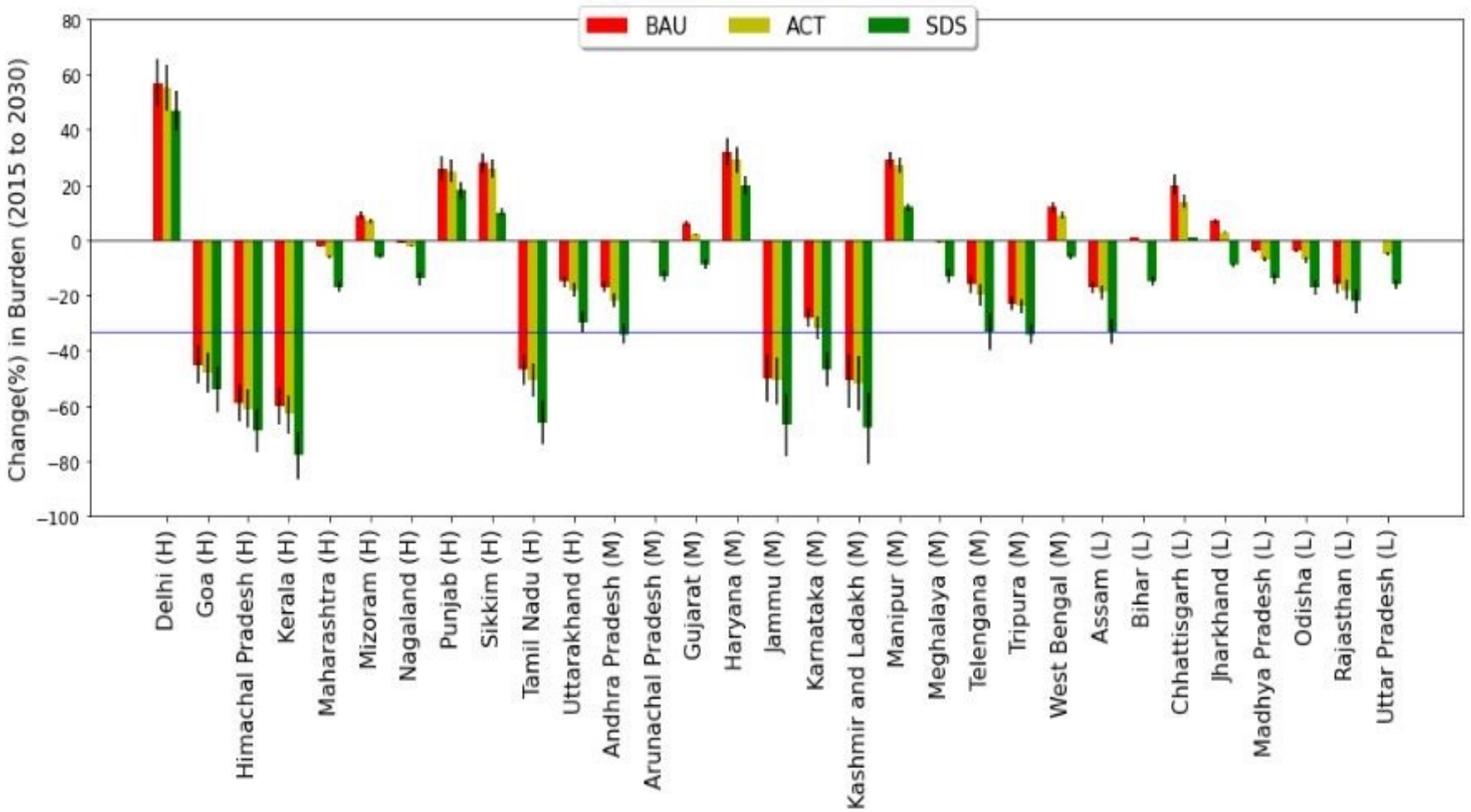


Meeting NCAP target & even the next interim target is not enough to reduce burden and meet SDG3.4 target uniformly [Sarkar et al., *in preparation*]

Projected Burden for Contrasting Pathways

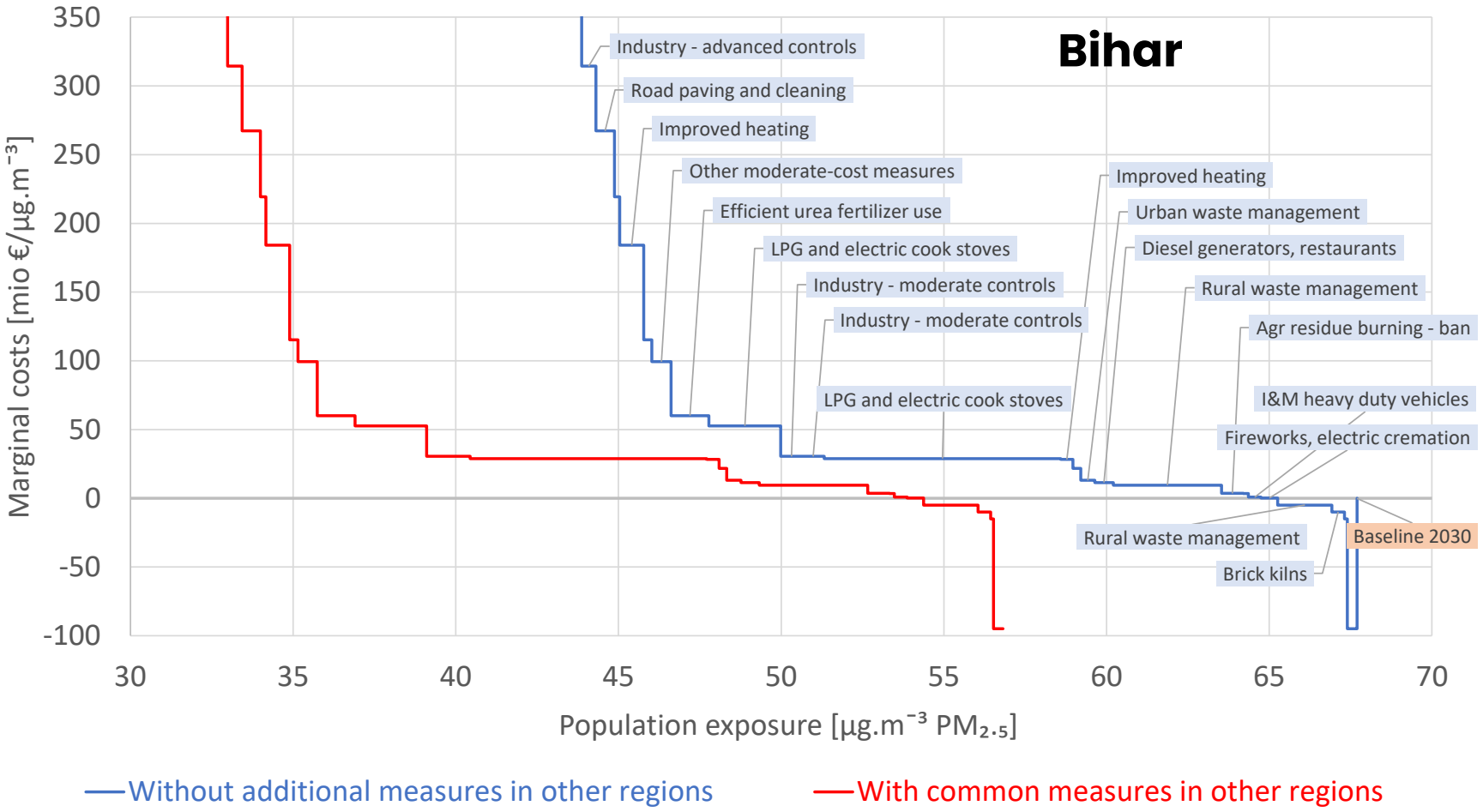


- BAU: Current mitigation efforts continue
- ACT: Advanced control technology in addition to current interventions in place
- SDS: Best possible reduction with strictest norms



Even the SDS pathway is not enough to reduce burden and meet SDG3.4 target [Sarkar et al., *in preparation*]

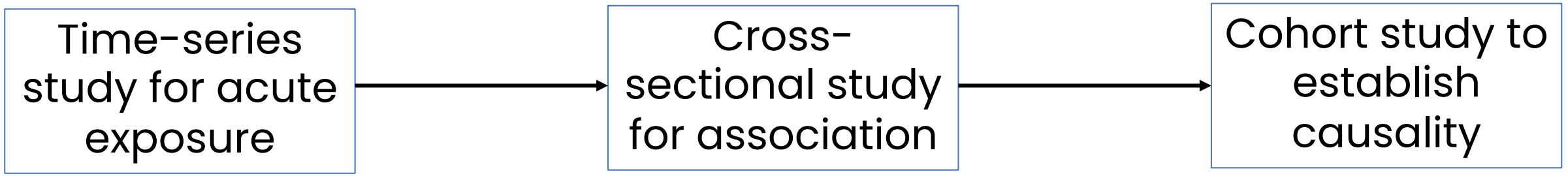
Cost for controls with & without co-operation



- 247 control measures can be adopted for Bihar
- Bihar cannot achieve WHO IT-1 target by 2030 on its own
- Initial 3 μg/m^3 reduction has potential of revenue generation
- Another 5 μg/m^3 reduction can be achieved at marginal cost
- If Bihar & all IGP states work together and implement common set of controls, Bihar can meet the WHO IT-1 target

Action in other IGP states would reduce net costs for domestic measures in Bihar from 1.6 billion Euro/year (unilateral case) to 160 million Euro/year

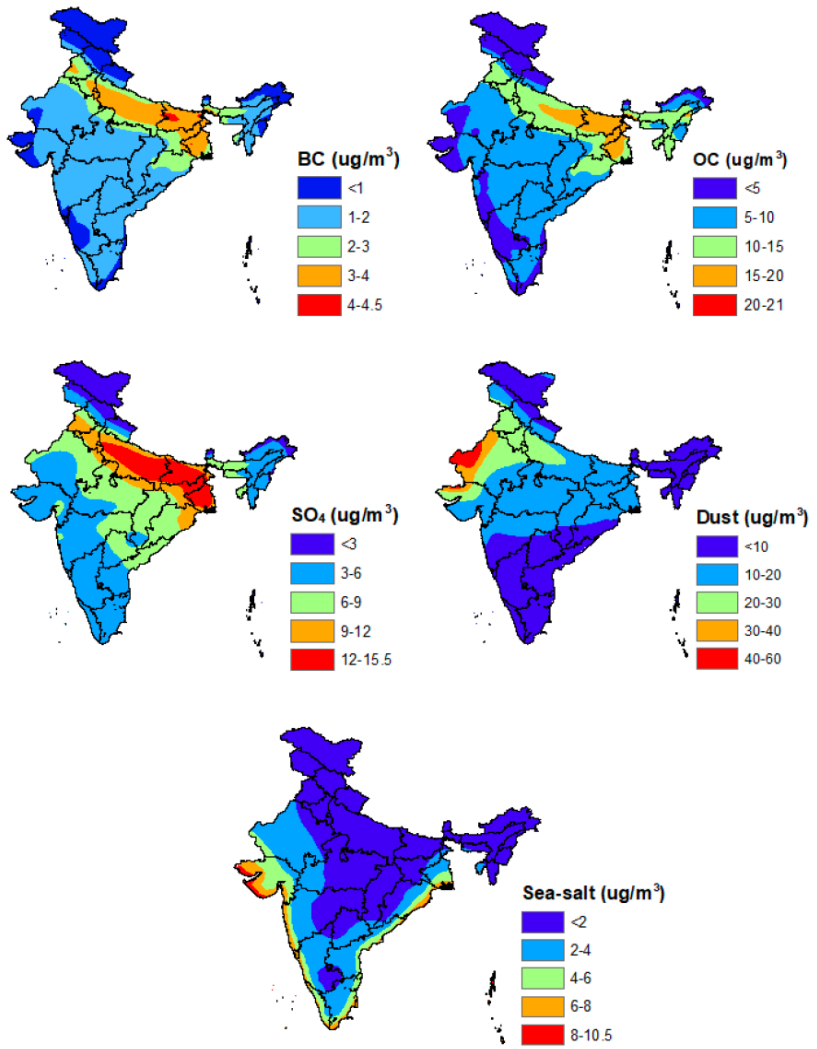
Does $PM_{2.5}$ composition matter?

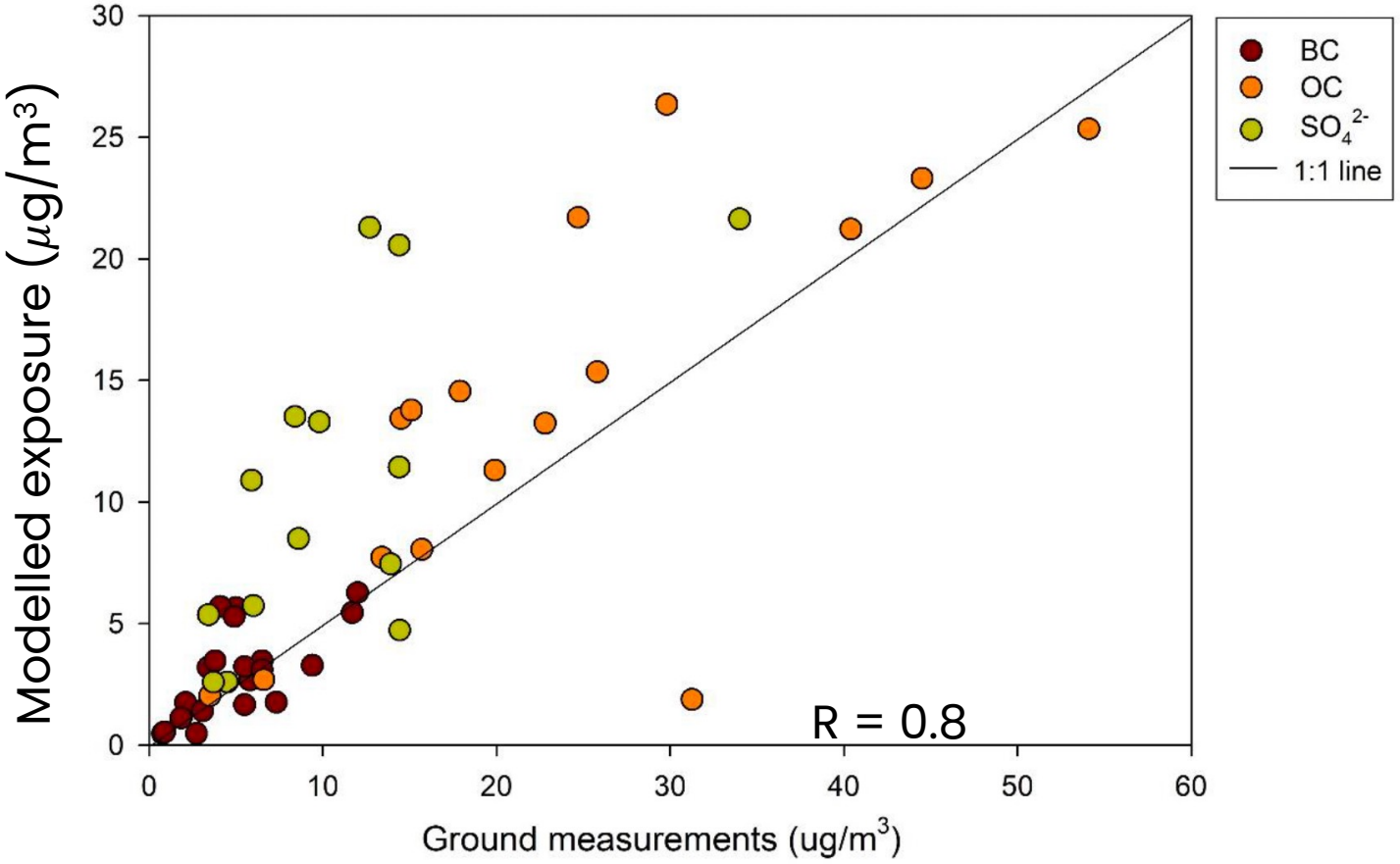


Challenge is availability of representative exposure data (for individual species – tagged to emission sectors)

Exposure to Individual Species & Sector

$$PM_{2.5,i} = f_{i,model} \times PM_{2.5,satellite}$$





[Chaudhary et al., 2023]

Differential association with $PM_{2.5}$ species

nature sustainability

ARTICLES

https://doi.org/10.1038/s41893-022-00944-2

Check for updates

Reducing the burden of anaemia in Indian women of reproductive age with clean-air targets

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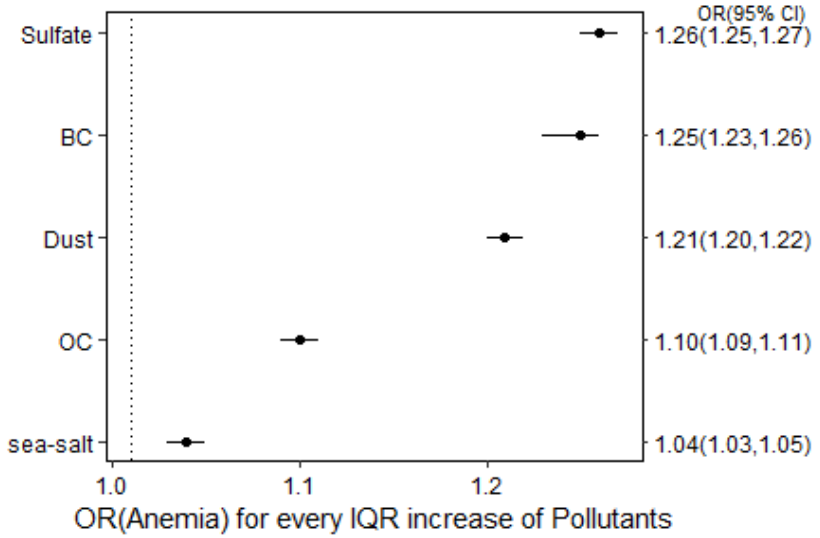
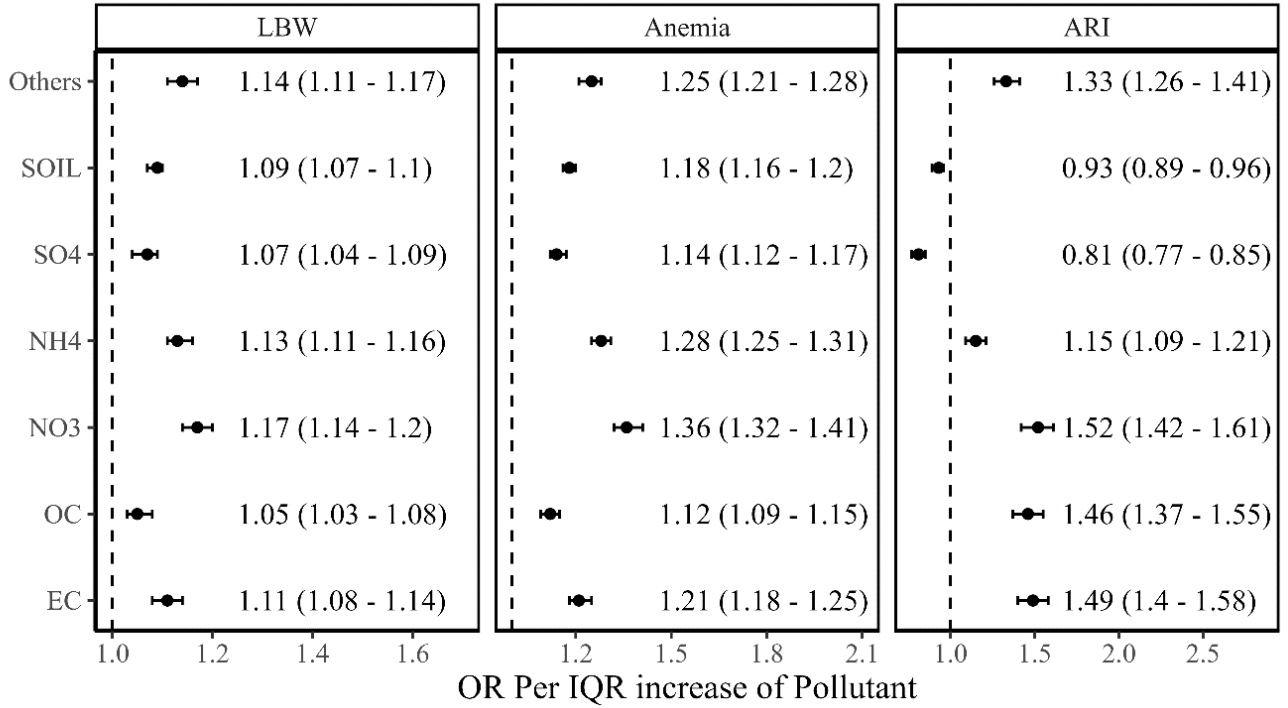
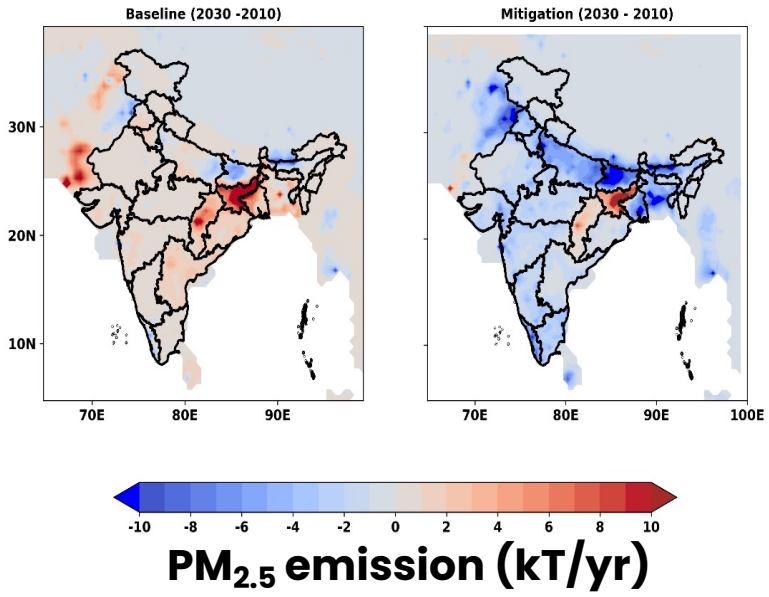


- Confounders adjusted – Diet, BMI, sex, wealth index, use of fuel, etc.
- Differential association for women & child health outcomes [Chaudhary et al., Nature Comm., in review]
- BC and secondary $PM_{2.5}$ show higher association

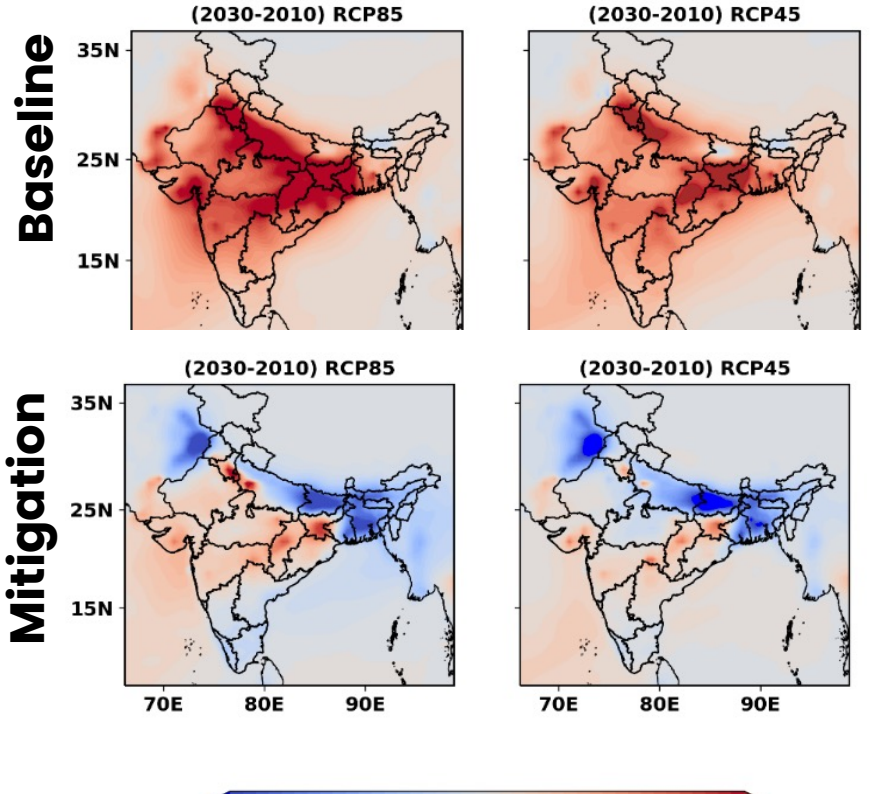


Climate Consequence



Anthropogenic $PM_{2.5}$ over India ($\mu g/m^3$)

	RCP8.5	RCP4.5
2010	41.4 ± 26.5	
2030 (Baseline)	61.1 ± 40.8	58.2 ± 37.5
2030 (Mitigation)	40.2 ± 27.5	39.2 ± 25.4



- Averted mortality in 'mitigation' scenario w.r.t. 'baseline' scenario is 380,000 (270,000-510,000)
- Tradeoff is 0.3-0.5 C additional warming in 'mitigation' scenario [Upadhyay et al., Sci. Rep., 2020]

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OPEN ACCESS

RECEIVED
23 May 2021

REVISED
29 September 2021

ACCEPTED FOR PUBLICATION
1 November 2021

PUBLISHED
22 November 2021

Aerosol-modulated heat stress in the present and future climate of India

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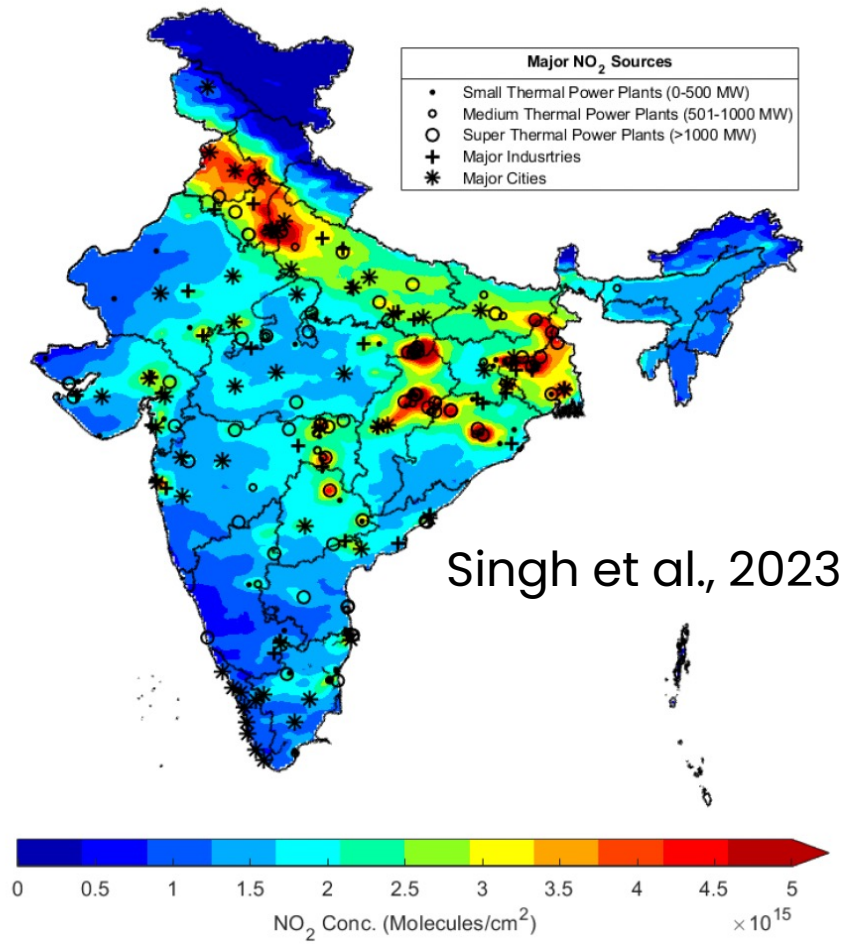
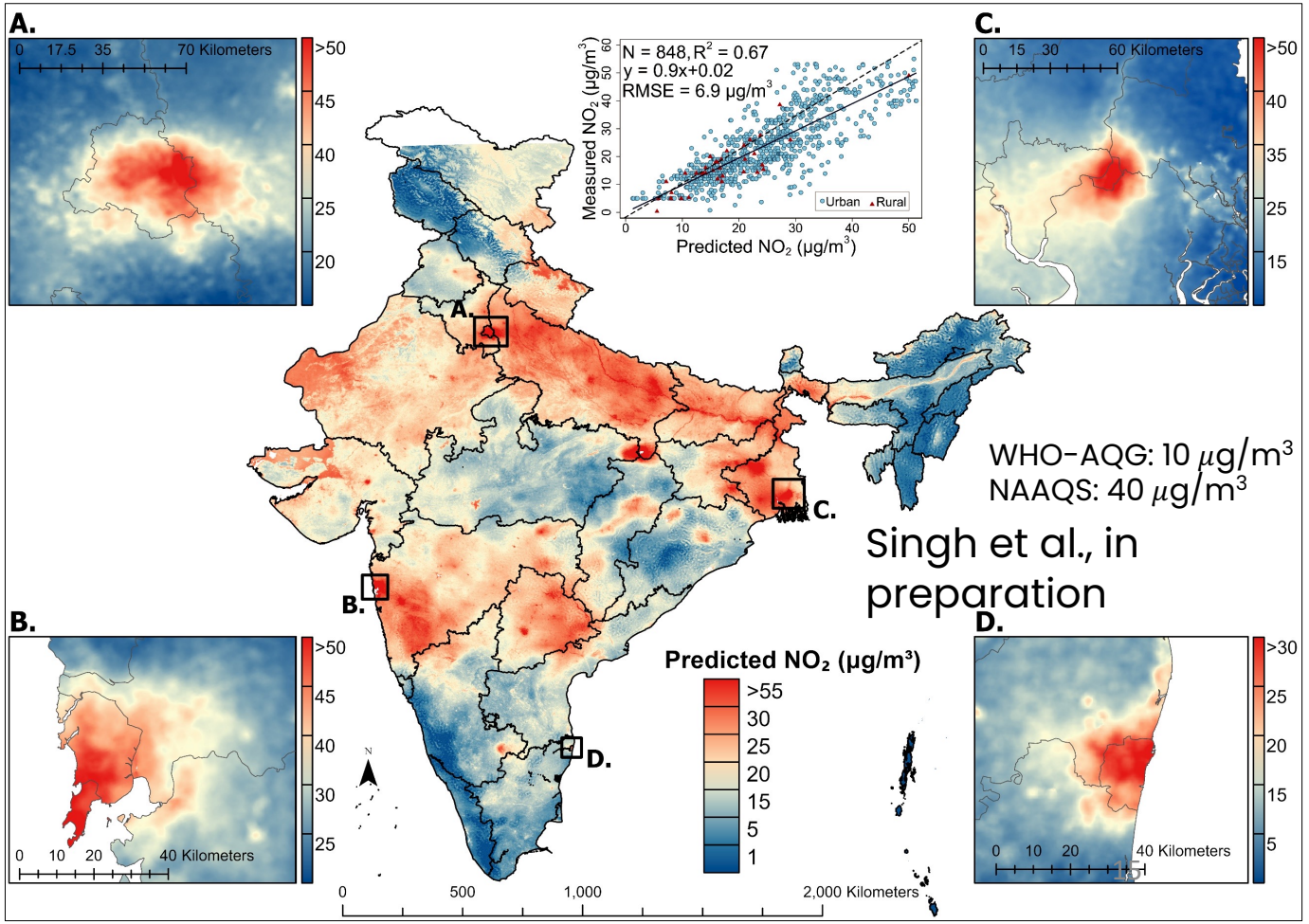
Keywords: heat stress, comfort class, aerosols, emission pathway, climate change, India

Moving towards multi-pollutant impact

- Air pollution is a deadly cocktail of various components
- Impacts of $PM_{2.5}$ may be modulated by other gaseous pollutants



Singh et al., 2023



Singh et al., in preparation

Way Forward for India

- Use indigenous exposure-risk function - set realistic air pollution reduction targets in view of health benefits

- South Asia needs to move towards air shed approach – inter-state and international co-operation is key in accelerated progress

- Understand climate, health & energy co-benefits of clean air – prioritize sectoral interventions

Thank You