Regional Source Contributions to Fine Particulate Matter and Attributable Mortality in South Asia

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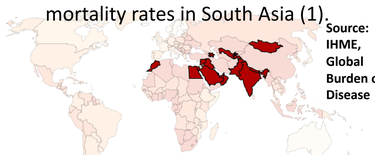
INTRODUCTION

MOTIVATION

- Exposure to fine particulate matter ($PM_{2.5}$) is associated with high mortality rates in South Asia (1).



Mortality per 100,000 people associated to outdoor air pollution due to **$PM_{2.5}$** and **ozone** in 2019

- Inadequate understanding of $PM_{2.5}$ **source contribution to mortality** based on **sectors** and **fuel types in South Asia**.

STUDY OBJECTIVE

Use satellite remote sensing and GEOS-Chem High Performance (GCHP) model to quantify the source sector and fuel type contributions to $PM_{2.5}$ mass and the associated disease burden, to improve public health in South Asia.

STUDY APPROACH

1) Use the Community Emissions Data System (CEDS-GBDMAPS) as base emissions and CEDS v2021-06 for 2019 and 2017 to develop updated anthropogenic emissions for 2019.

2) Use the stretched grid capability (2) of 3D GCHP v13.4.3 model to simulate surface-level $PM_{2.5}$ concentrations.

3) Downscale sensitivity simulations with a hybrid satellite derived $PM_{2.5}$ product which combines multiple AOD datasets and observation-based predictor variables at a 1 km resolution.

4)Obtain fractional contribution of sector and fuel types to $PM_{2.5}$ mass and attributable mortality

NOVELTY COMPARED TO PAST WORK

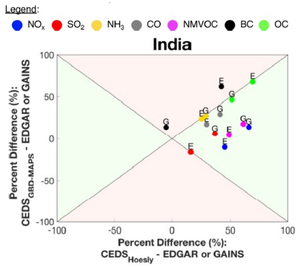
Previous air quality and health burden studies in South Asia have not extensively addressed the impact of **regional air quality contributions** to public health.

Previous modeling studies in South Asia used satellite AOD, emission datasets, simulations, and diseases burden from **2017 or older**.

We use emission datasets, simulations, satellite AOD and diseases burden for 2019 using an advanced modeling capability not used before.

1.EMISSIONS in South Asia for 2019

CEDS GBD-MAPS emission inventory for atmospheric pollutants from sectors and fuel specific sources, includes regional inventory for India (SmoG)



CEDS GBDMAPS advantages :

- Provides better estimate of emissions compared to existing emissions inventory for India and rest of South Asia.
- Includes fuel specific information including solid biofuel, coal, process and oil and gas useful for fuel-based sensitivity simulations.
- Includes National level emissions inventory for India (SMoG) that provides spatio-temporally resolved emissions for inputs to estimate air quality and climate impacts.
- SMoG provides publicly available dataset on air pollutants, including OC, SO_2 , CH_4, CO, ozone precursors NO_X, NMVOCs), short lived climate pollutants (SLCPs) including BC, O_3 and green houses gases (GHGs) like CO_2 , N_2O for India.

Scaling CEDS GBDMAPS to 2019 :

- We obtained the emissions ratios of 31 different species from CEDS v2021-06 for 2019 and 2017.
- We use the emission ratios as scaling factors to obtain updated emissions for 2019 which includes the GBD-MAPS regional emissions information.

Base Emissions : **CEDS GBD-MAPS (2017)**

Scale Factors= $\frac{\textbf{CEDS 2019}}{\textbf{CEDS 2017}}$

FinalEmissions 2019 = **Base Emissions x Scale Factors**

2. GEOS-Chem High Performance (GCHP)

GCHP is an offline implementation of GEOS-Chem, a chemical transport model driven by NASA Goddard Earth Observing System (GEOS) meteorological data for parallel simulations (3), detailed in Martin et al., (2022)

GCHP advantages :

1. Stretched-grid capability for higher resolution to resolve nonlinearities in user-selected regions with two-way coupling for long range transport.
2. Better parallelization using MPI to enable simulation on thousands of cores

3. MODEL BASE, SENSITIVITY SIMULATION, EVALUATION & SECTORAL CONTRIBUTION

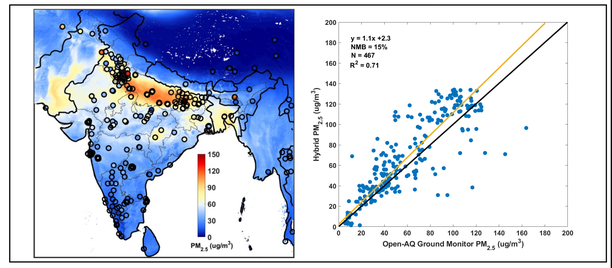
Stretched grid simulations of $PM_{2.5}$ mass are conducted with the GEOS-Chem High Performance model, downscaled to hybrid satellite product

GEOS-Chem High Performance (v13.4.3)

Simulations Parameters
Horizontal Resolution: C60 } ~ 55 km
Stretch Factor: 3.0
Chemistry: Full chemistry mechanism
Meteorology: MERRA-2 **Simulation length:** 2019 full year

Downscaling & Evaluation

Base simulations from GCHP scaled to fine resolution at 1 km using hybrid satellite- derived estimates of surface $PM_{2.5}$ mass from van Donkelaar et al. (4)



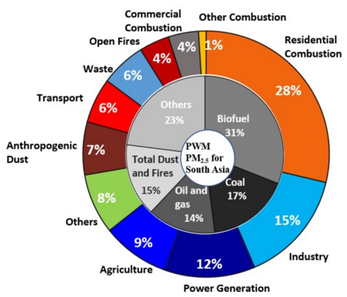
- retains simulated fractional speciation and seasonality
- improves observational agreement

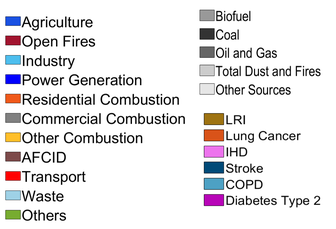
$$[\boldsymbol{PM_{2.5}}]_{source} = [\boldsymbol{PM_{2.5}}]_{base\ sim.} - [\boldsymbol{PM_{2.5}}]_{source\ sensitivity\ sim.} \qquad (\%\boldsymbol{PM_{2.5}})_{source} = \frac{[\boldsymbol{PM_{2.5}}]_{source}}{\sum_{j=1}^{24}[\boldsymbol{PM_{2.5}}]_j}$$

$$(\%\ \overline{\boldsymbol{Contribution}})_{Source} = \frac{\sum_{i=1}^{n}[\%\ \boldsymbol{PM_{2.5}}]_{source,i} \times [\boldsymbol{Hybrid\ PM_{2.5}}]_i \times \boldsymbol{Population}_i}{\sum_{i=1}^{n}[\boldsymbol{Population}]_i}$$

4. SENSITIVITY SIMULATIONS FOR SECTORS, FUEL TYPES AND SPECIES RESULTS

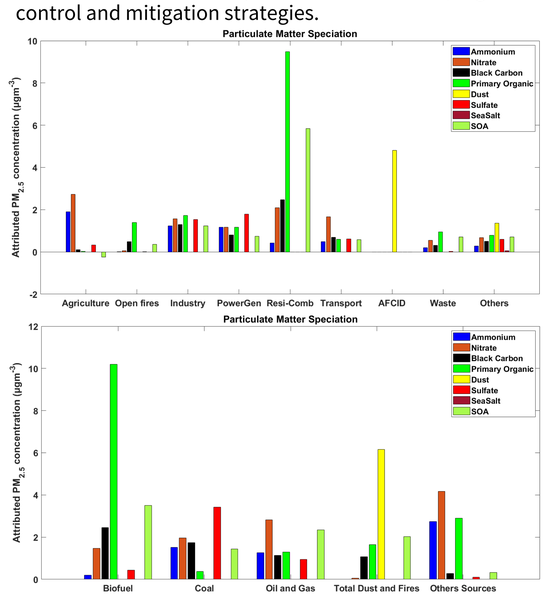
Gridded sectoral contributions to $PM_{2.5}$ mass are obtained using emission sensitivity stretched grid simulations in GCHP to understand sectoral contribution to





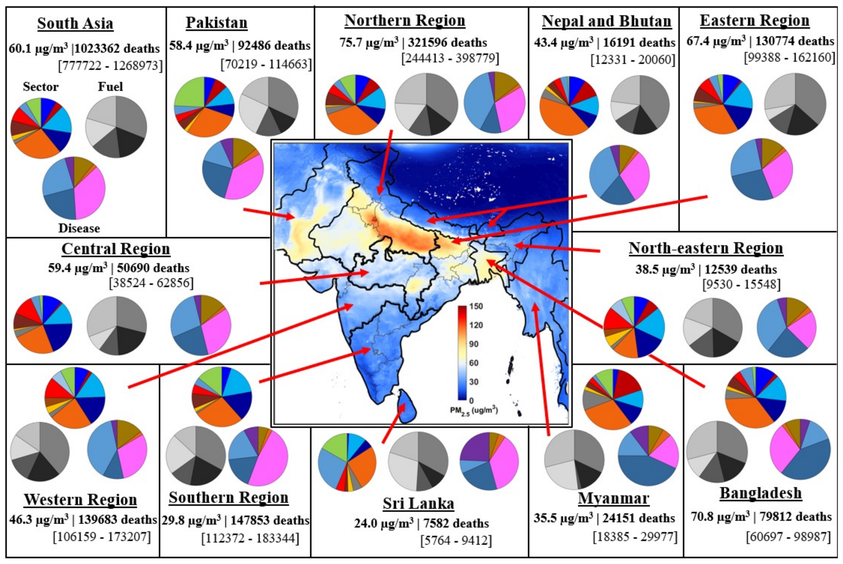
Chemical composition of **$PM_{2.5}$** shows reducing Primary Organics from residential combustion/ Biofuel sector can reduce overall **$PM_{2.5}$** mass by ~ 10 ug/m^3.

Chemical composition of **$PM_{2.5}$** provides information on mean concentrations of chemical components attributable to each sector particularly important for developing control and mitigation strategies.



5. SECTOR AND FUEL CONTRIBUTIONS TO $PM_{2.5}$ ASSOCIATED DISEASE BURDEN IN SOUTH ASIA

Simulation results and mortality burden estimate for sectoral contributions to $PM_{2.5}$ disease burden



6. CONCLUSION

- **Residential combustion**, **industry** and **power generation** and **biofuel** are major **source-based** and **fuel-based** contributors to mortality in South Asia.
- High $PM_{2.5}$ concentrations in **North** and **Eastern** India is associated with about **50 % of total mortality in South Asia**.

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