Scientific meeting on Effects of Air Pollution on Health, Human Capital and Sustainable Development in India, UNEP-DSE-Boston College, New Delhi, 17-18 Jul, 2019

Emission pathways and source apportionment of ambient air pollution in India

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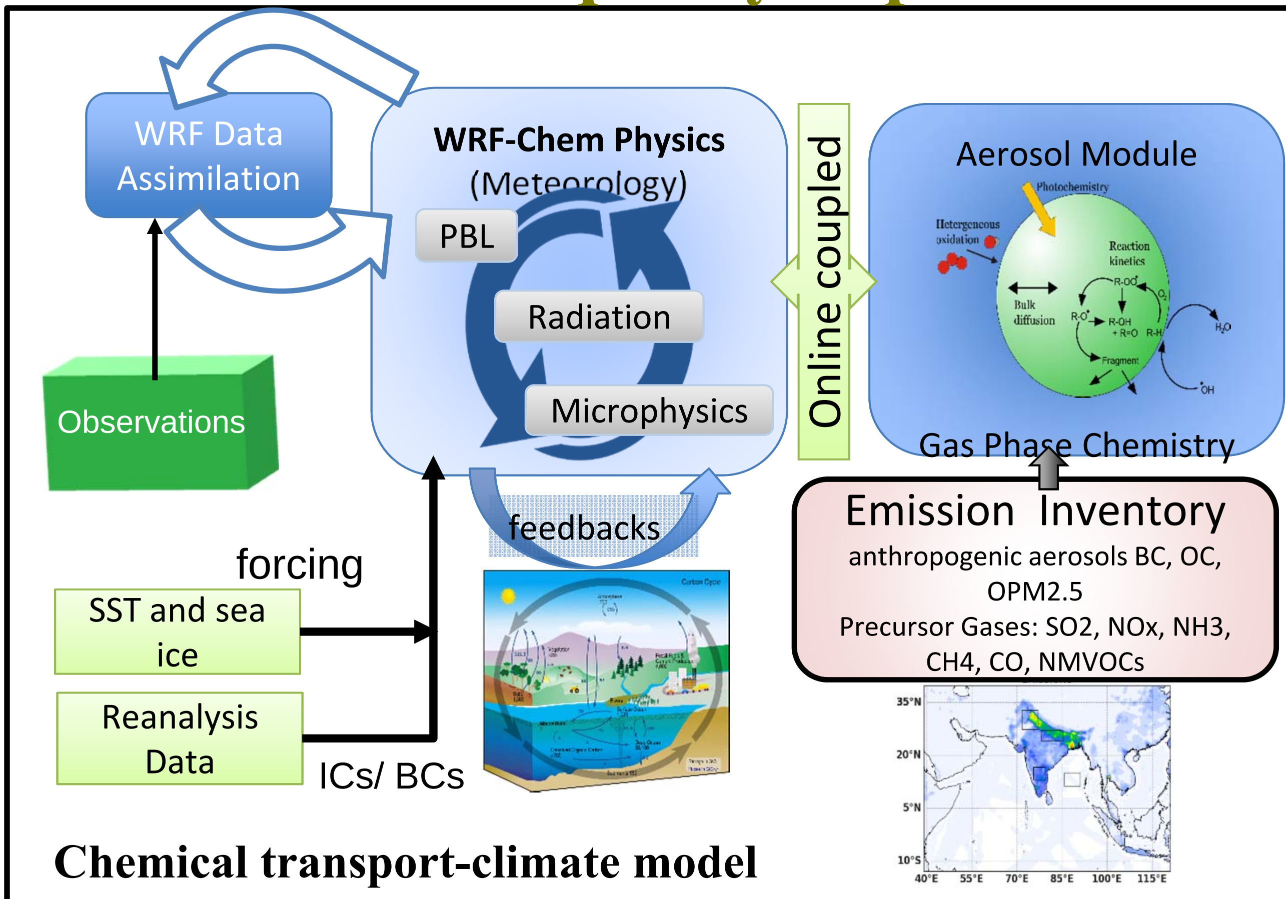
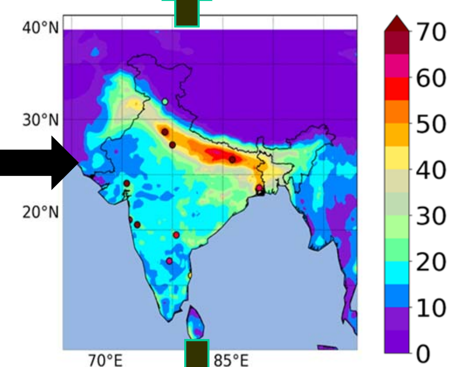
Department of Chemical Engineering
Indian Institute of Technology Bombay

Particle and Aerosol Research Laboratory (PeARL)

Climate and air-quality impacts of energy-use emissions



Process understanding: Aerosol induced changes in radiation, temperature, clouds and rainfall



Environmental policy: Mitigation strategies; co-benefits to climate and air-quality

Laboratory and field studies: Multi-phase aerosol processes; carbonaceous aerosol optical properties

Energy-emissions modelling: multi-pollutant emissions inventory & scenarios, decision support models

Emissions modelling: engineering model approach

Building from globally consistent emission datasets, needs inclusion of regional details, in fuels, technology divisions and energy-use practices, with refined spatial resolution.

IPCC TIERS

Tier 1

- Global tech / fuel / EF

Tier 2

- Country specific fuel characteristics
- Technology based EF

Tier 3

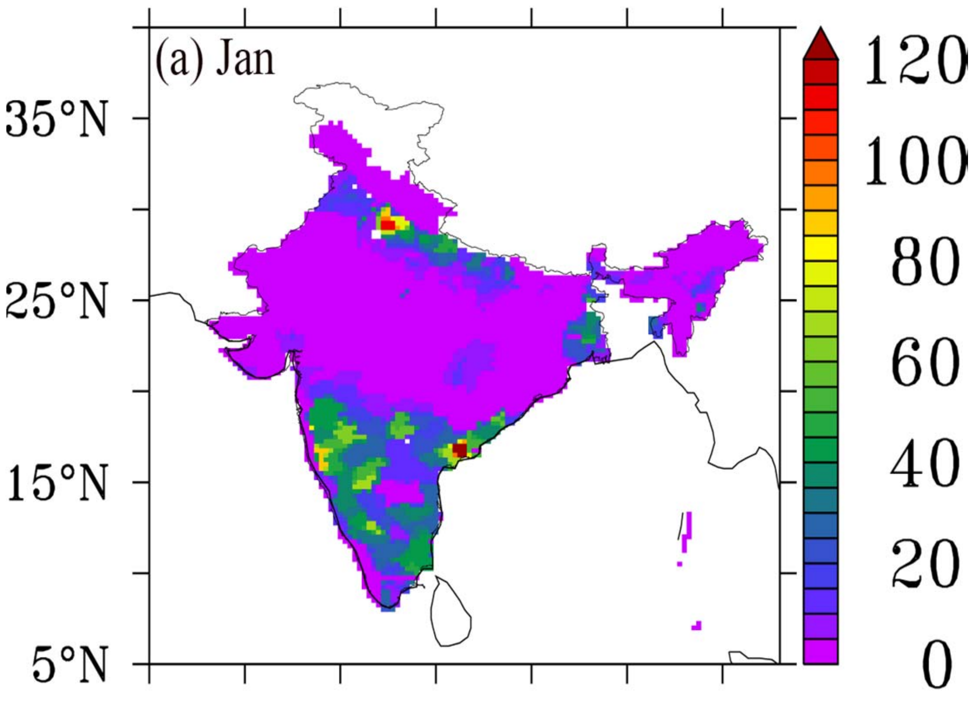
- Detailed activity/technology levels
- Measured regional EF

ENERGY SECTORS

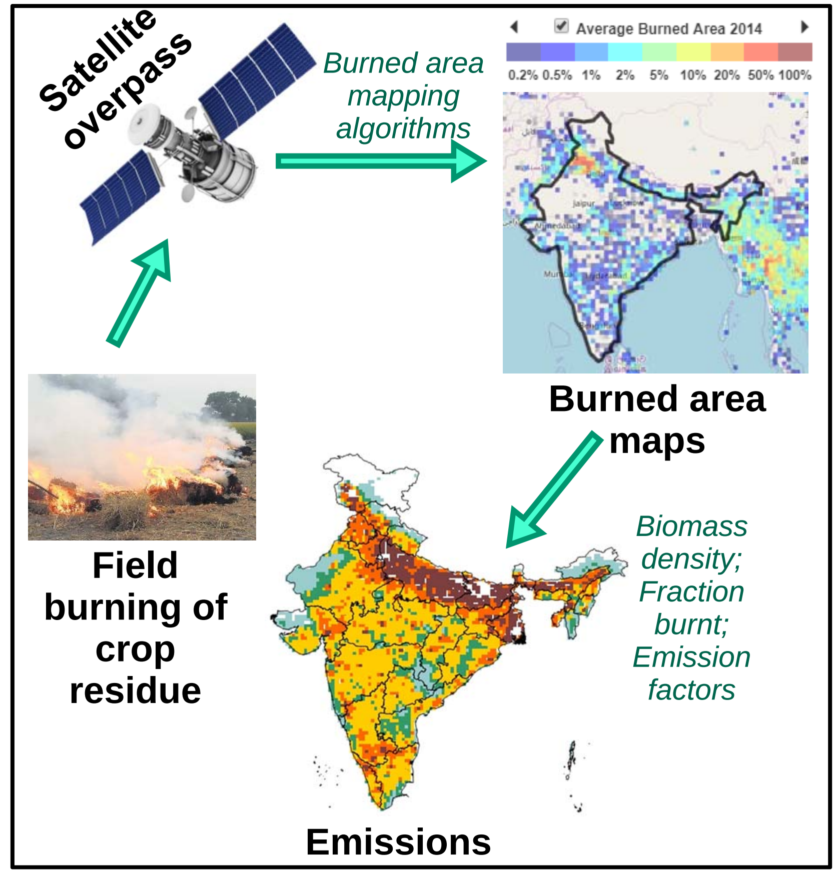
Sec	Industry	Transport	Residential	Agriculture	Informal
Source Categories	• Thermal power • Heavy industry • Light industry	• On-road gasoline • On-road diesel • Railways /Shipping/ Aviation	• Cooking biofuels • Cooking LPG /kero • Lighting kero lamps	• Agriculture residue burning • Agriculture diesel use	• Brick production • Food processing
Technologies	PC boiler, Stokers, oil-fired boilers, gas turbines, coke ovens, refineries	2-wheelers, 3-wheelers, Cars, LDV, HDV, Buses, CNG vehicles, Super-emitters, age distribution	Traditional biomass stoves, LPG stoves, kerosene stoves, kerosene wick lamps	Open field burning, Different agricultural residues, diesel tractors, diesel pumps	Bull's Trench Kiln – Fixed and moving chimney, Clamps, Zig-zag firing, VSBKs, wood-boilers

Harmonizing satellite based (e.g. GFED-4s) and inventory based emissions: agricultural residue burning

Inventory based $PM_{2.5}$ emissions (tons/grid /month)



Satellite based emissions



Uncertainties

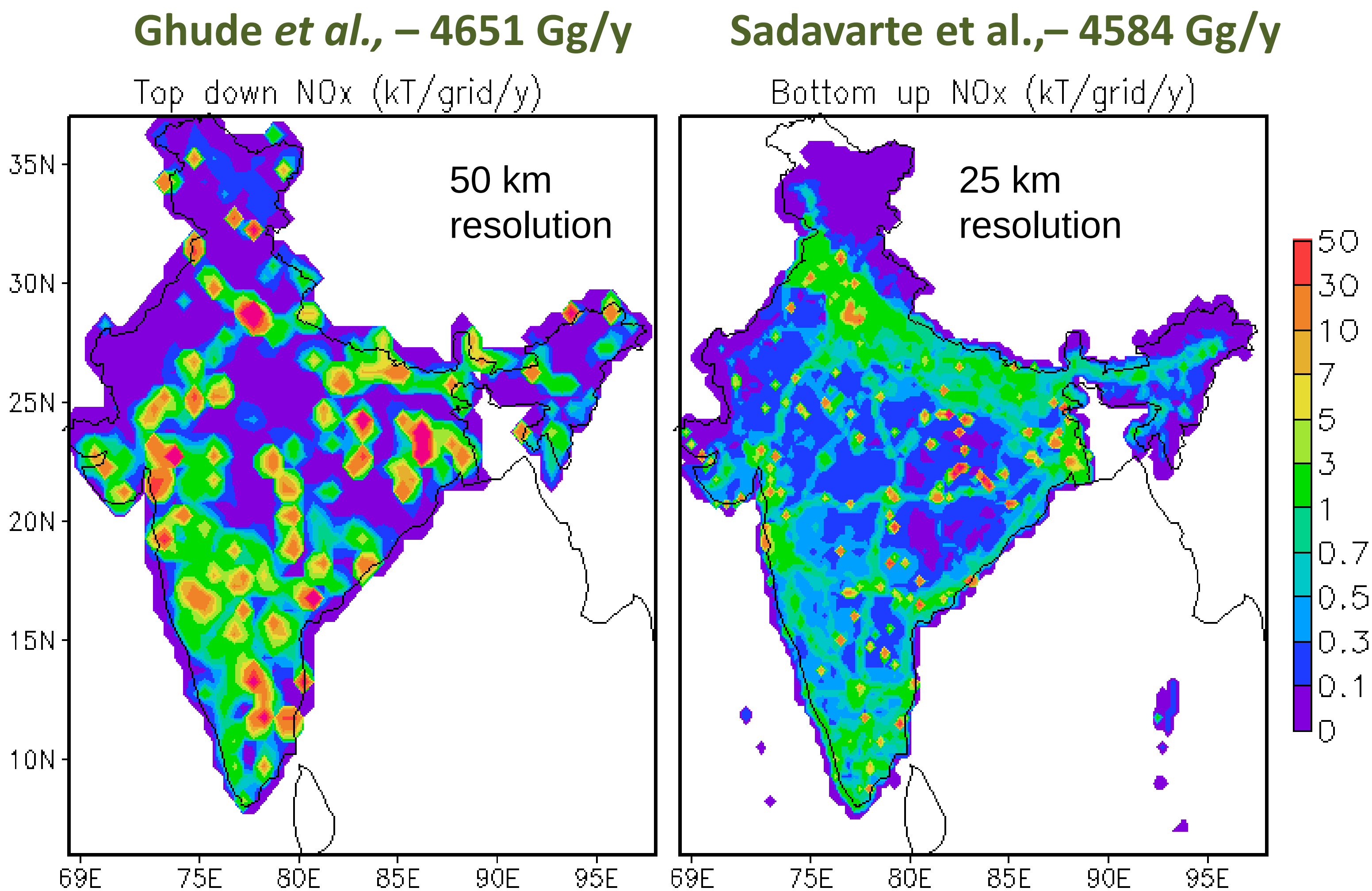
Inventory: Assumed “fraction of residue burned in field” and “waste to grain ratio”

Satellite based: Satellite detected “burned area” and assumed “biomass density”

Both: Emission factors

Sadavarte and Venkataraman, 2014 AE; Pandey et al., 2014 AE; Pandey and Venkataraman, 2014 AE

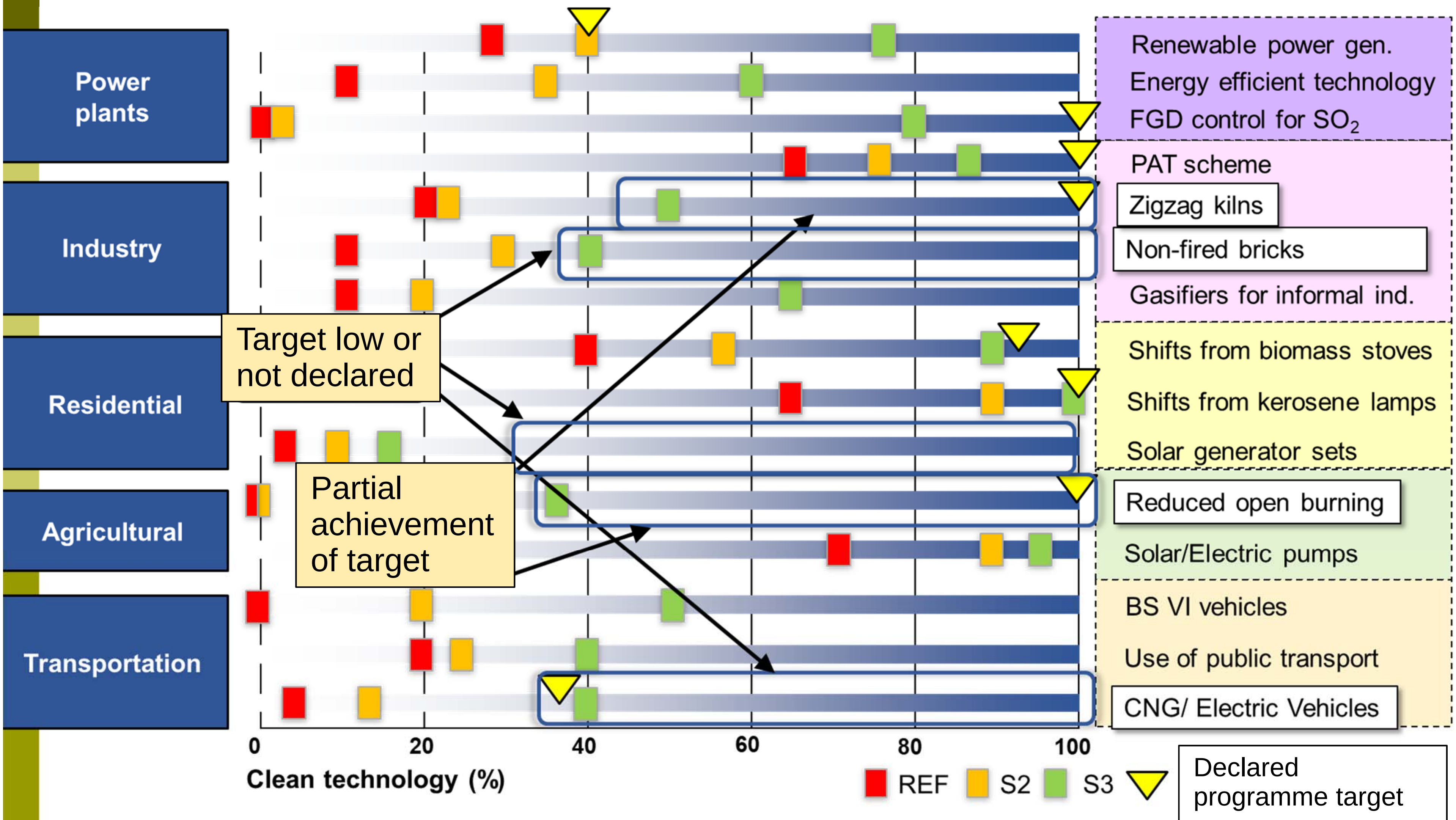
Constraining emission uncertainty with satellite-based estimates



Magnitude and spatial distribution optimized to capture prominent features of top-down satellite-based emissions.

Sadavarte and Venkataraman, 2014 AE; Pandey et al., 2014 AE; Pandey and Venkataraman, 2014 AE

Future emission scenario development (example of 2030)

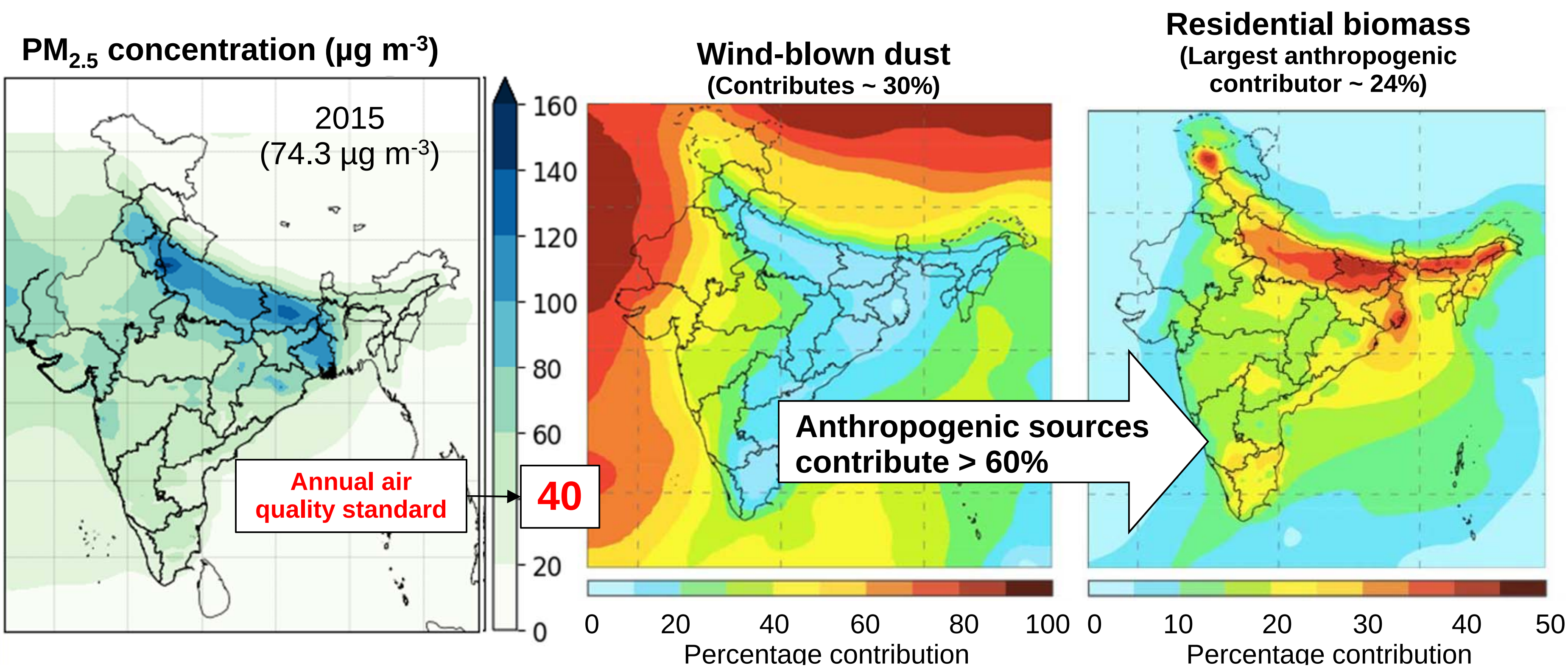


Atmos. Chem. Phys., 18, 8017–8039, 2018
https://doi.org/10.5194/acp-18-8017-2018

Atmospheric Chemistry and Physics
Open Access
EGU

Source influence on emission pathways and ambient $PM_{2.5}$ pollution over India (2015–2050)

Chandra Venkataraman[1,2], Michael Brauer[3], Kushal Tibrewal[2], Pankaj Sadavarte[2,4], Qiao Ma[5], Aaron Cohen[6], Sreelekha Chaliyakunnel[7], Joseph Frostad[8], Zbigniew Klimont[9], Randall V. Martin[10], Dylan B. Millet[7], Sajeev Philip[10,11], Katherine Walker[6], and Shuxiao Wang[5,12]

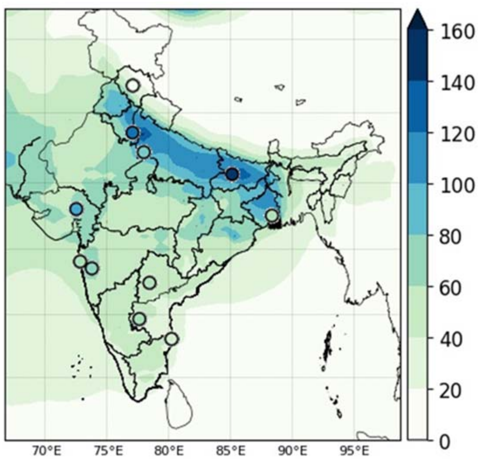


Model evaluation (GEOS-Chem; 50 km x 67 km)

- **11.2% NMB** of model simulated concentrations and in-situ measurements
- **33% NMB** of model simulated vs satellite detected AOD
- Species seasonal cycle OK; wintertime underestimation

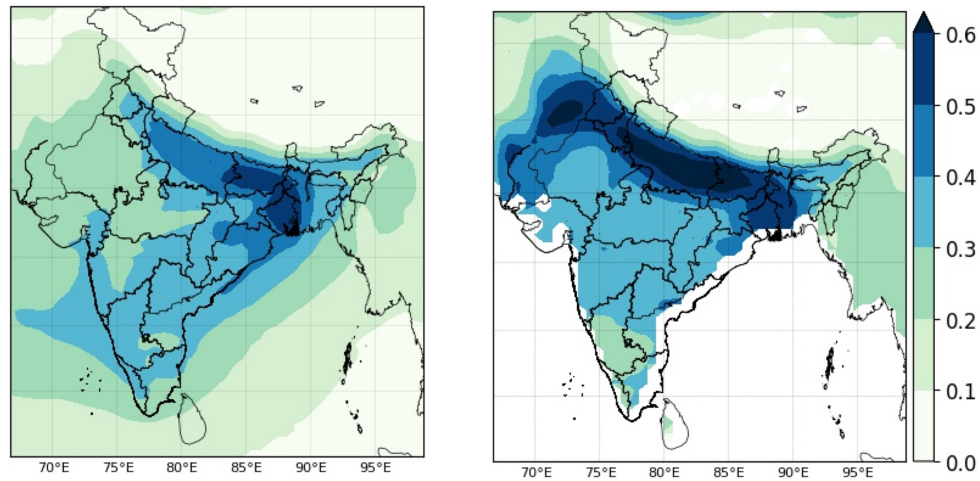
Concentrations (µg/m[-3])

In-situ (circles) v/s GEOS-Chem



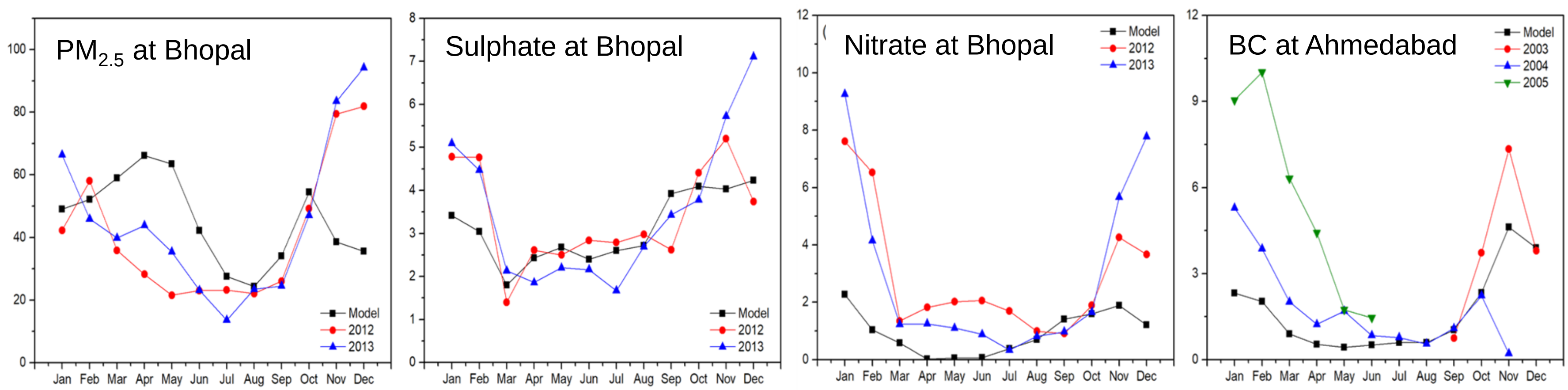
Model AOD

MODIS AOD



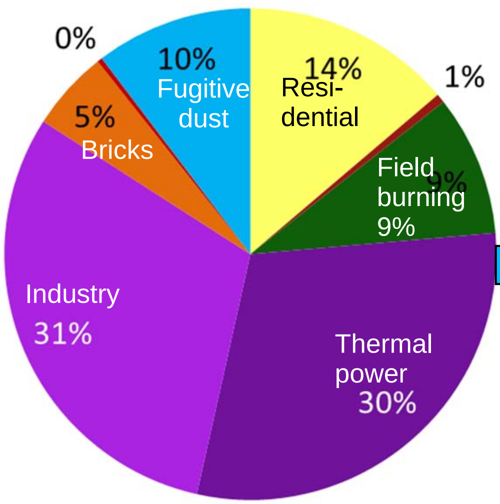
AOD

Chemical species

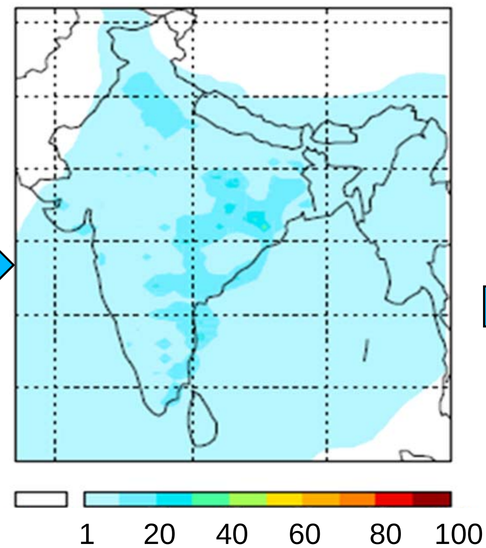


Venkataraman et al., 2017, ACPD

Detecting missing sources – anthropogenic dust – using ground measurements

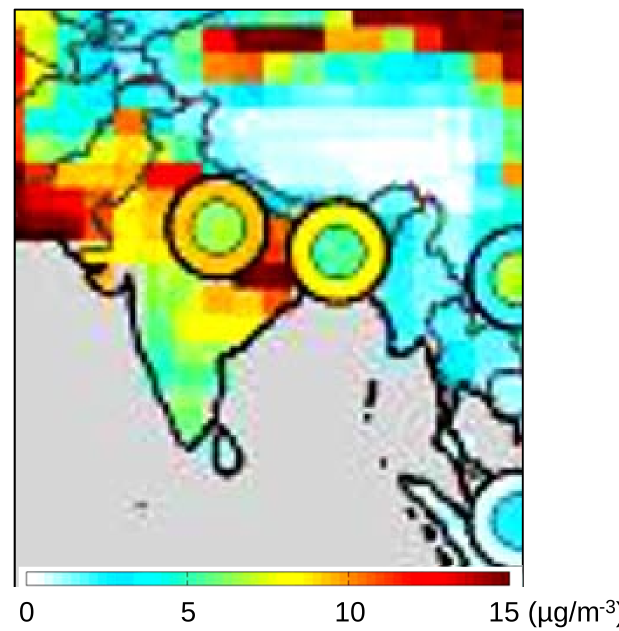


AFCID
2015 emissions
3.2 MT y^{-1}



AFCID
% contribution to
ambient PM2.5 conc.

Total Dust



Annual mean PM2.5 total dust concentrations (µg/m^{-3})

(GEOS-Chem simulated; SPARTAN campaign measurements (inner circle))

AFCID = Anthropogenic, Fugitive, Combustion and Industrial Dust

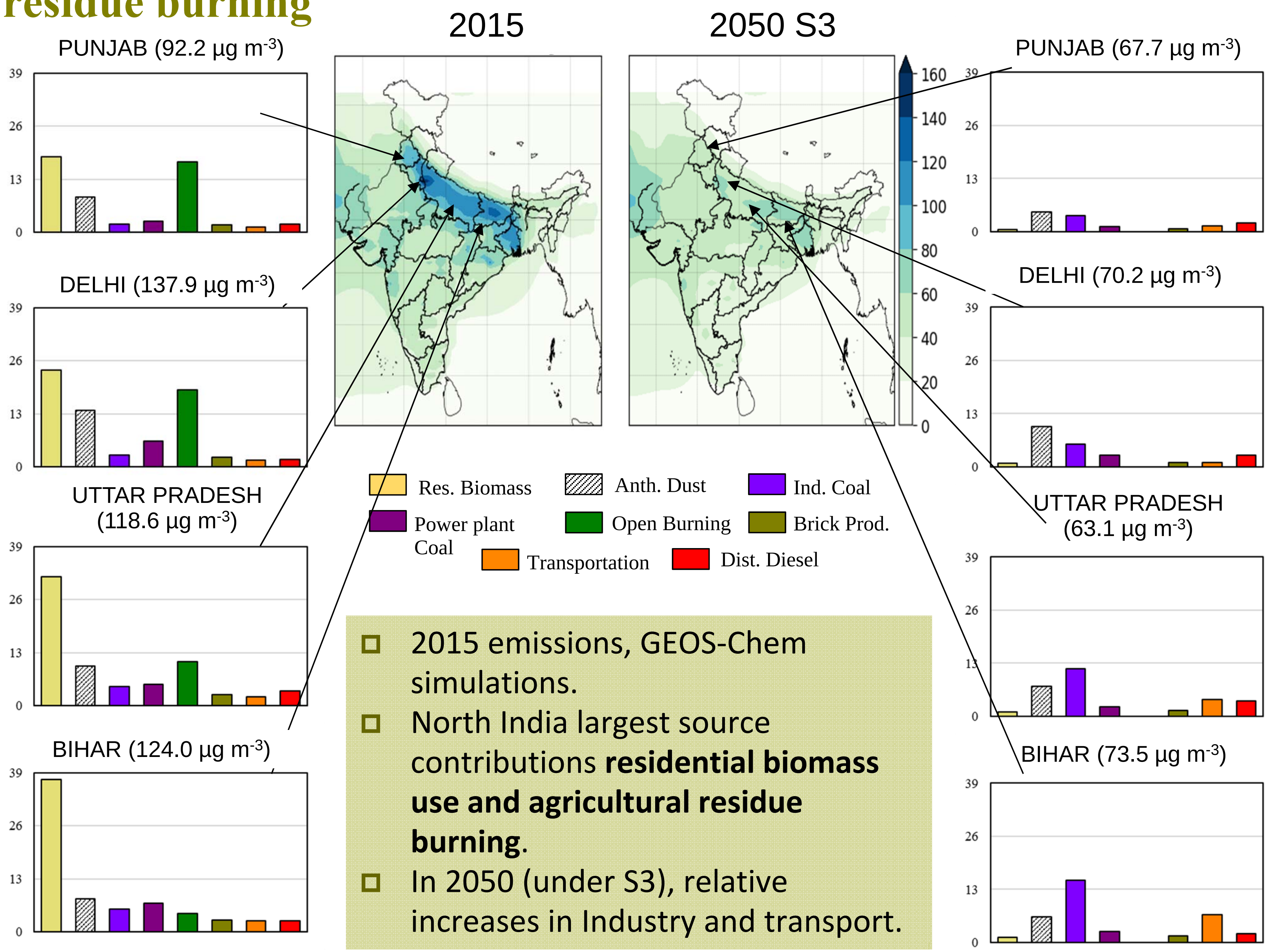
AFCID: coal fly ash, mineral matter from combustion, fugitive dust (re-suspended road dust, and dust from construction).

Including AFCID improves measured vs modelled total dust globally (R^2 from 0.06 to 0.66; SPARTAN sites).

Simulations including AFCID reduce the bias in total dust measured over Asia from -17% to -7%.

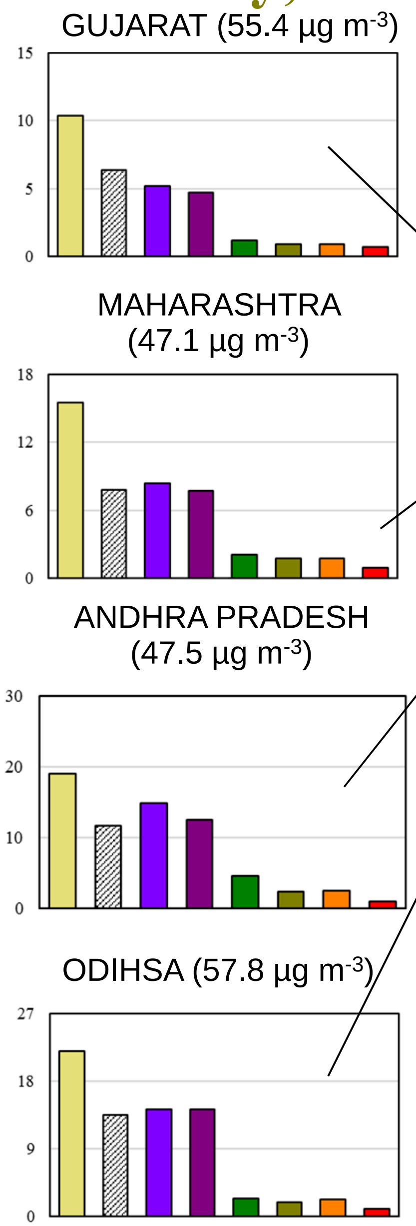
Philip, …Venkataraman et al., 2017 Env Res Lett

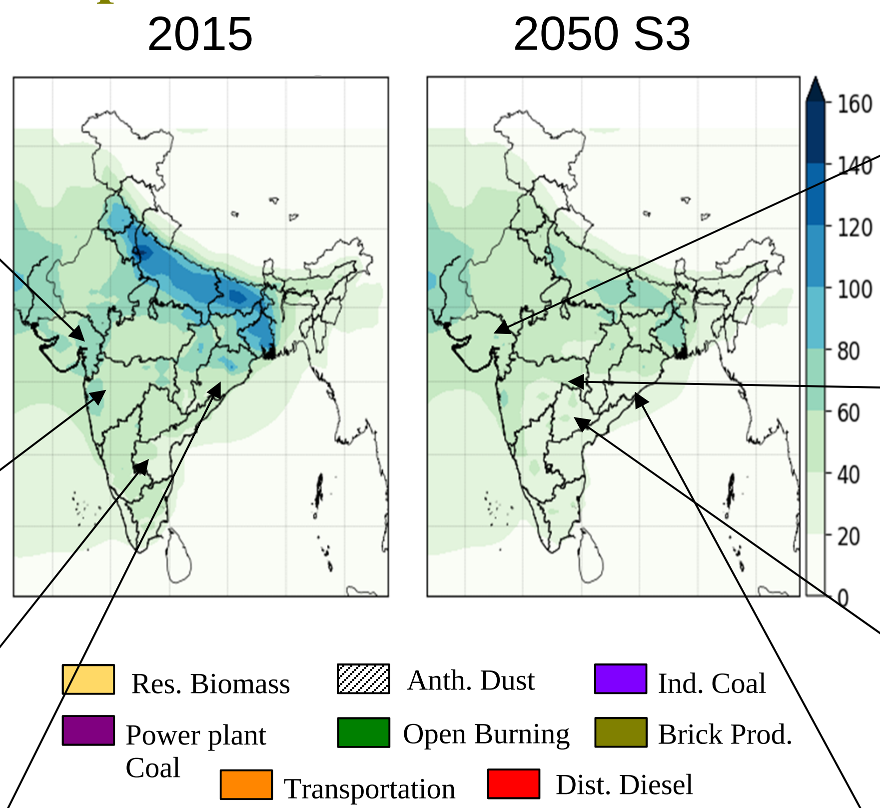
North India sources: Residential biomass & agricultural residue burning

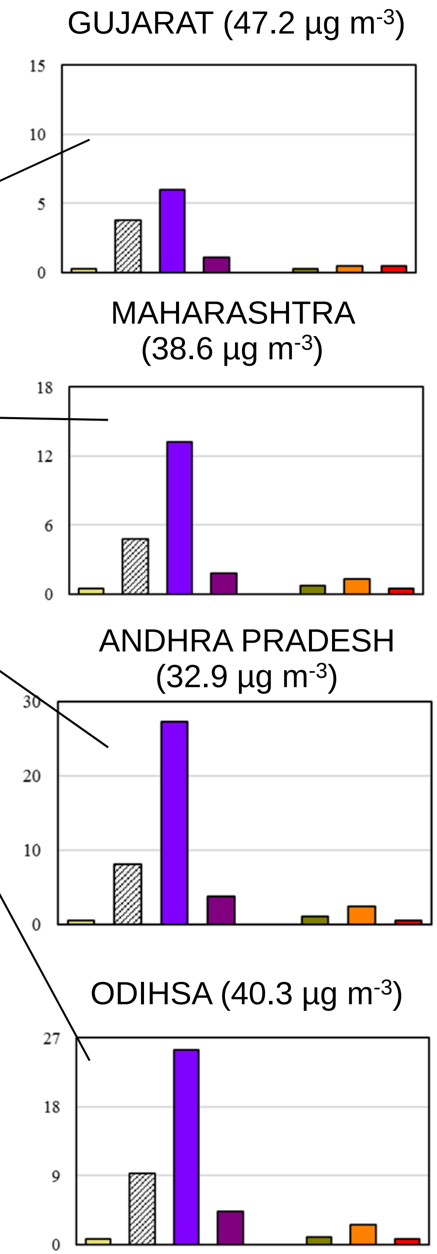


- 2015 emissions, GEOS-Chem simulations.
- North India largest source contributions **residential biomass use and agricultural residue burning**.
- In 2050 (under S3), relative increases in Industry and transport.

Peninsular India sources: Residential biomass and Industry, thermal power



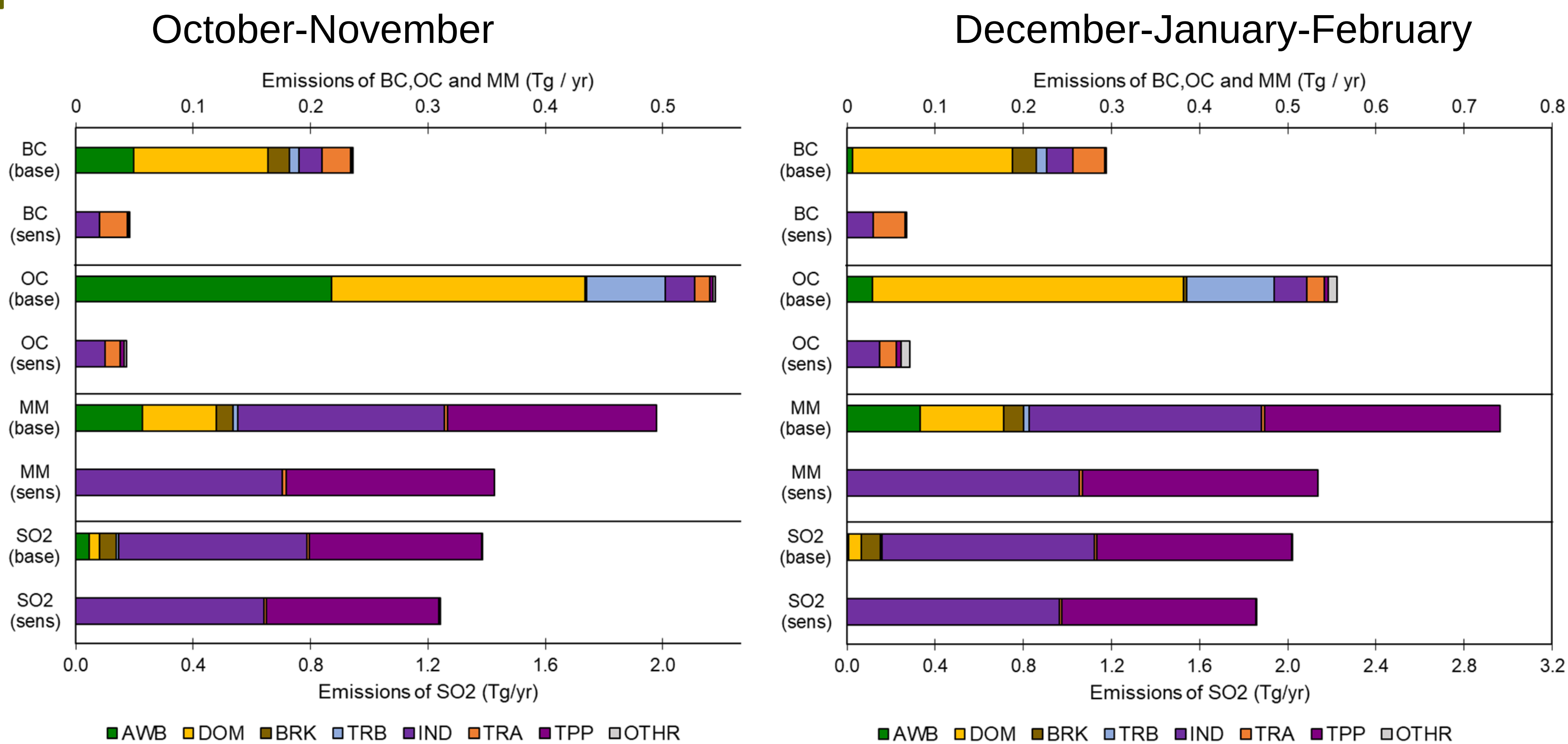




- Peninsular India source contributions dominated by **residential biomass use and industry/thermal power** (Anth Dust is largely coal fly-ash).
- In 2050 (under S3), large relative dominance fo industry.

CV1

Influence of carbonaceous aerosol sources on wintertime air-quality



Agri resi; resi bio; bricks, trash; industry; transport; thermal power; other

- BC & OC in Oct-Nov dominated by agricultural residue burning emissions; in Dec-Jan-Feb by residential biomass fuel.
- Mineral matter & SO_2 largely from industry, thermal power.
- Baseline emissions – all sources “on”; sensitivity emissions – major carbonaceous aerosol sources “off” - Agri res, resi biomass, bricks & trash burning.

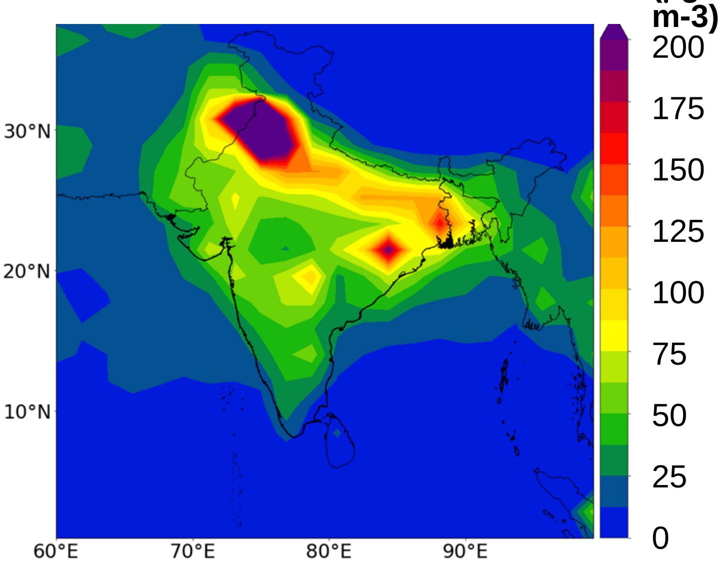
Slide 12

CV1 Chandra Venkataraman, 7/17/2019

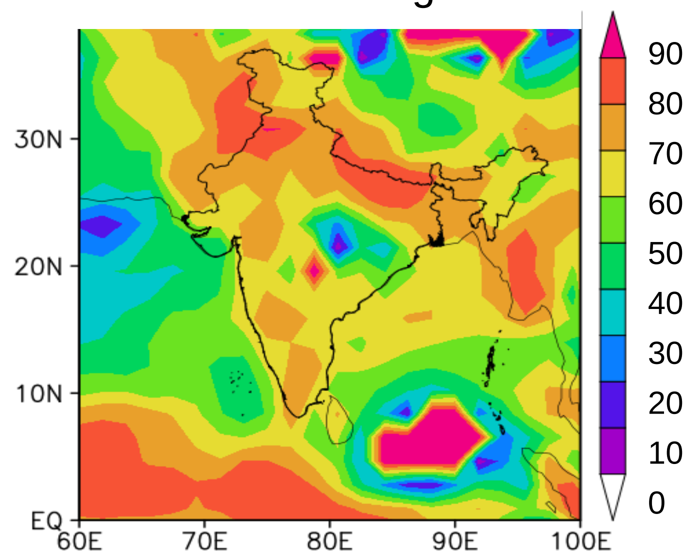
Wintertime air quality mitigation: ECHAM6-HAM2 simulations

- Wintertime air-quality mitigation of **60-90%** possible with control of **residential biomass + agri residue burning + brick kilns + trash burning.**

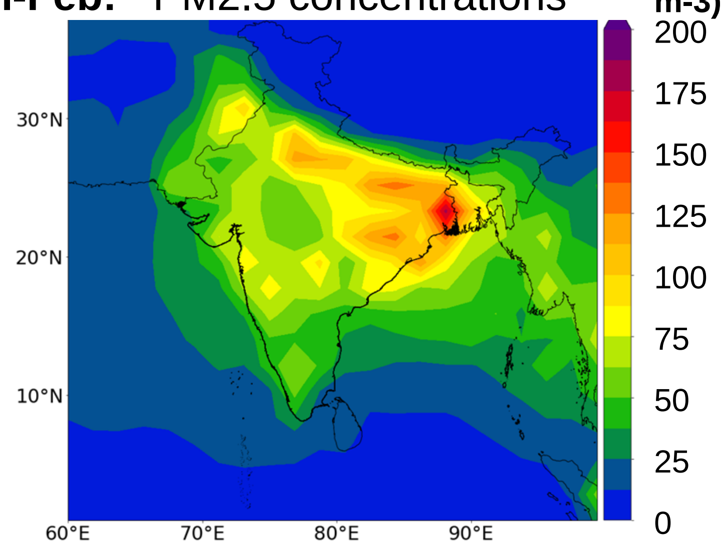
Oct-Nov: PM2.5 concentrations



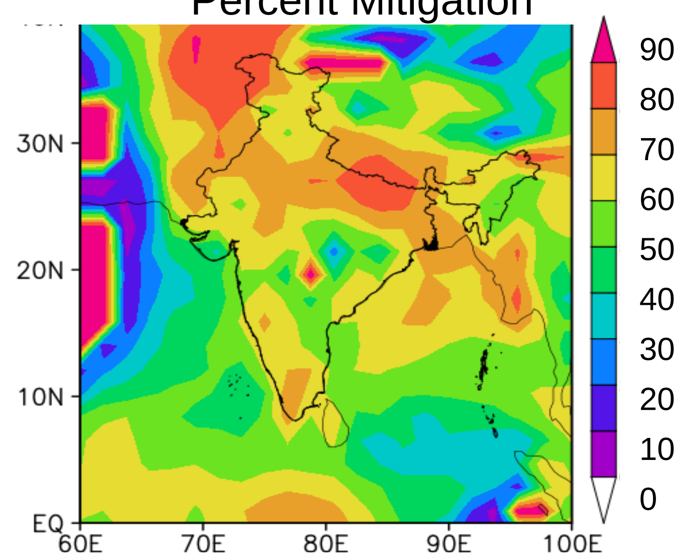
Percent Mitigation



Dec-Jan-Feb: PM2.5 concentrations



Percent Mitigation



(Venkataraman et al., 2019, under preparation)

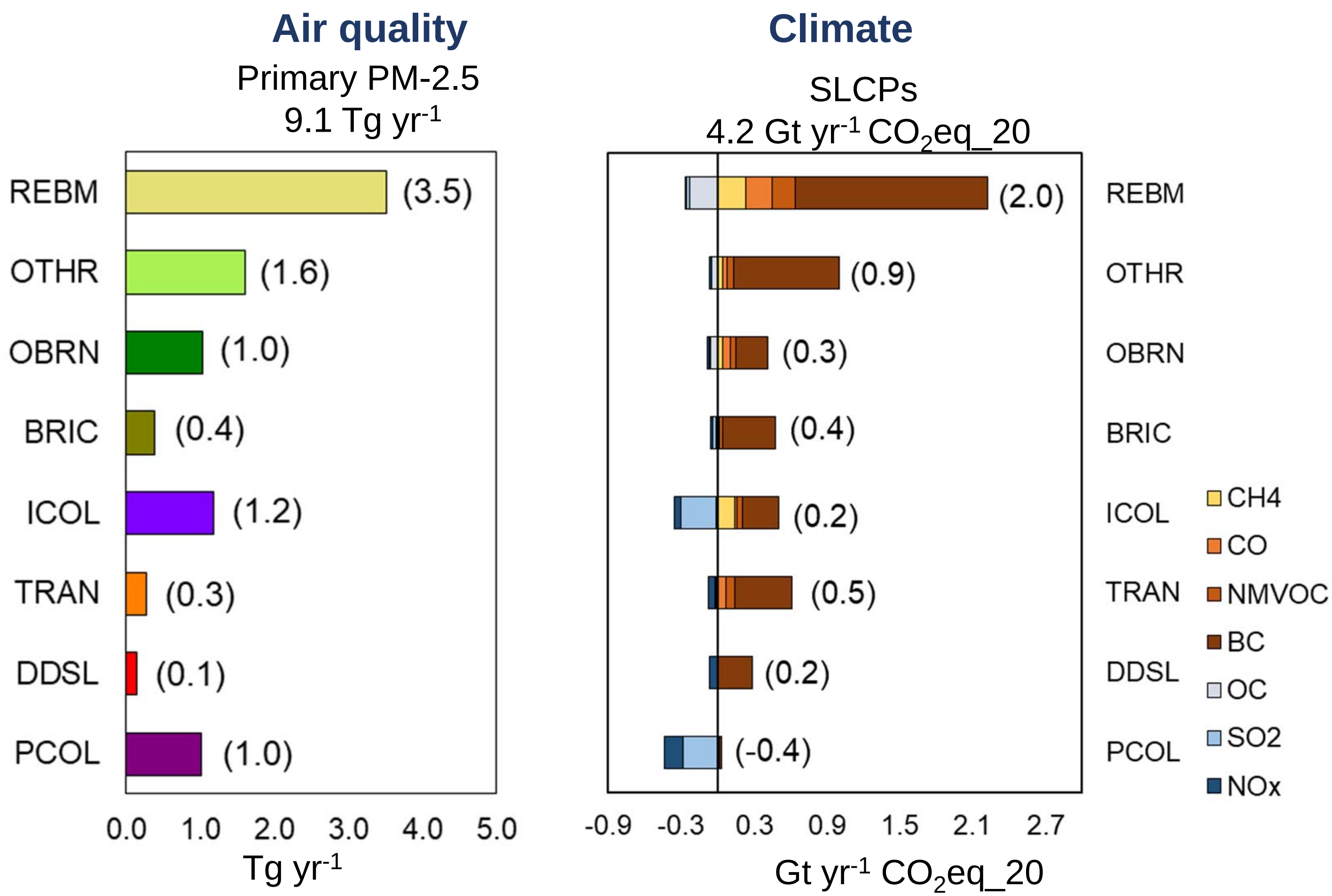
Many air pollutants are short-lived climate pollutants

- The 24th Conference of the Parties, Katowice, to the United Nations Framework Convention on Climate Change (UNFCCC), requires national reporting on gaseous SLCPs, including CH4, CO, NOx, NMVOCs and SO2, while particulate SLCPs like black carbon are under consideration (UNFCCC 2018).

Species	GWP_{20}	GWP_{100}
CH_4	83.9	28.5
NMVOC	14	4.5
NO_x	16.7	-10.8
CO	5.9	1.9
BC	2421.1	658.6
OC	-244.1	-66.4
SO_2	-141.1	-38.4

[IPCC AR5]

Air-quality and climate impact of emissions



REBM: Residential biomass;
OTHR: lighting (kerosene lamps), informal industry, trash burning and fugitive dust**;**
OBRN: agri. Residue burning;
BRIC: brick production;
ICOL: Industries;
TRAN: Transport;
DDSL: Distributed diesel (agri. Pumps, tractors, DG sets) ;
PCOL: Power plants;

Sectors with largest emissions (therefore mitigation potential) of both air pollutants and “net-warming SLCPs” are **residential biomass, “others” (kerosene lighting+trash burning+informal industry) agricultural residue burning and fired-brick production.**

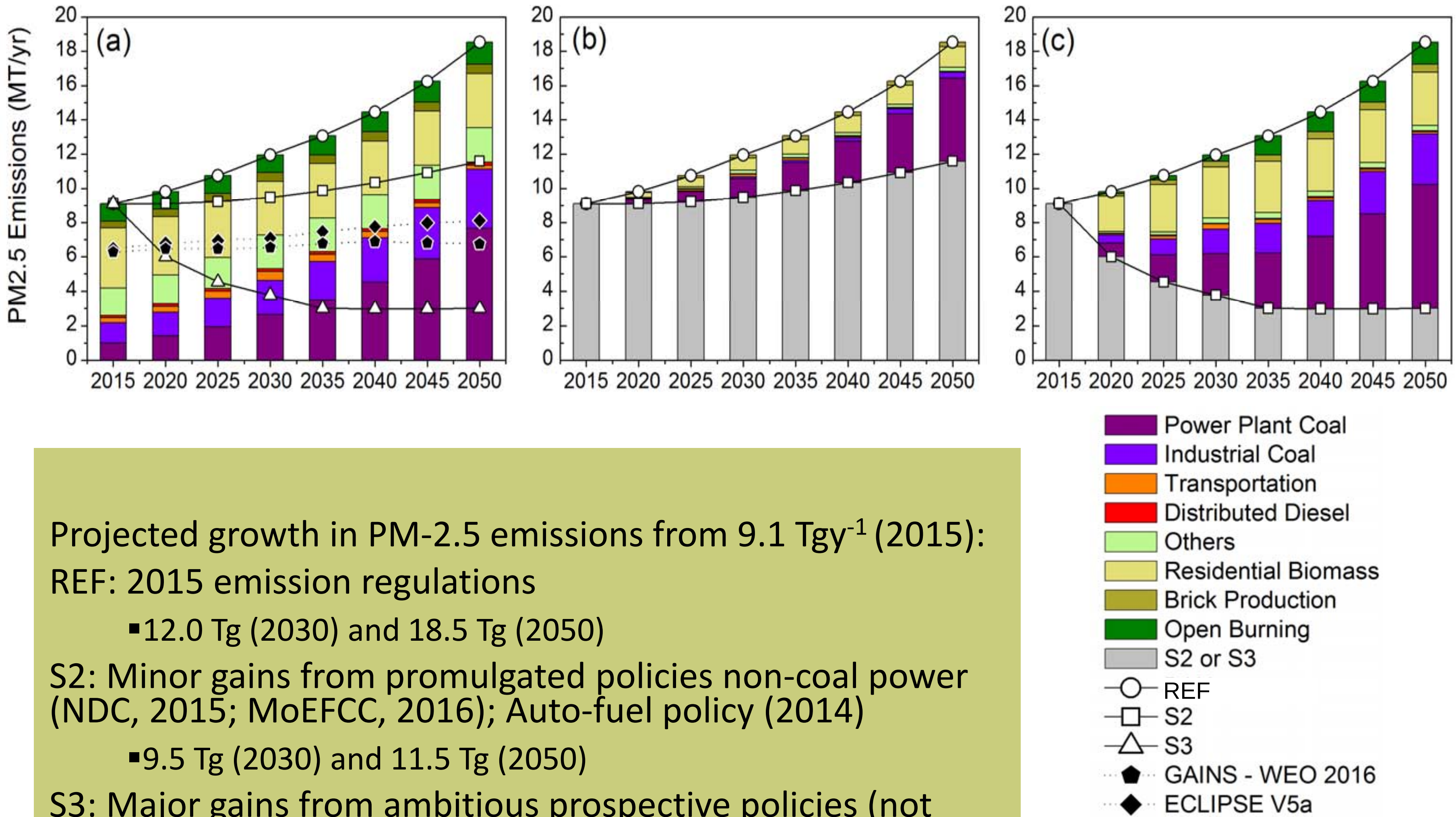
Recommendations

- Emission regulation beyond industry and transport
  - Address numerous, dispersed, hard-to-control sources and verify their shut-down (residential biomass energy, agricultural residue burning, trash burning and small fires, fired-brick production /informal industry).
  - Implementation and verification at city, district, state levels.
- Synergy in regulations/policy
  - Linkages needed among climate, air-quality, clean energy and sustainable development programmes, to prioritise interventions with multiple co-benefits.
- Deployment of a robust Air Quality Management system
  - Buy-in from all stakeholders.
  - Air quality measurement network, with data assimilation (mtulitple in-situ and satellite sensors) for PM-2.5 concentration fields over India.
  - Multiple modelling methods for robust quantitative source-apportionment.
  - Development of city, state and national emission inventories.

Thank you,
Questions welcome!

Extra slides

Evolution of future Indian PM-2.5 emissions



Projected growth in PM-2.5 emissions from 9.1 Tgy^{-1} (2015):

REF: 2015 emission regulations

- 12.0 Tg (2030) and 18.5 Tg (2050)

S2: Minor gains from promulgated policies non-coal power (NDC, 2015; MoEFCC, 2016); Auto-fuel policy (2014)

- 9.5 Tg (2030) and 11.5 Tg (2050)

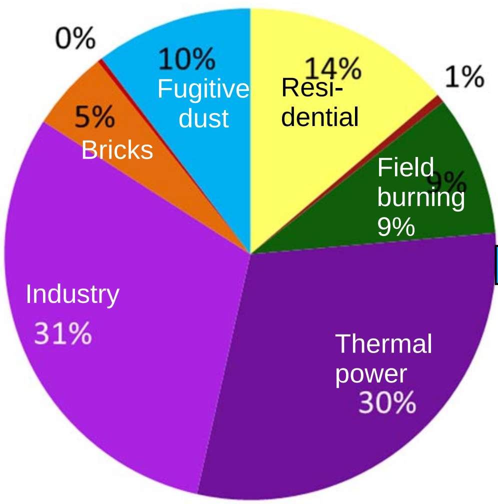
S3: Major gains from ambitious prospective policies (not formulated)

- 3.8 Tg (2030) and 3.0 Tg (2050)

("Others" includes residential lighting (kerosene lamps), informal industry (food and agro-product processing), trash burning and fugitive dust)

Venkataraman et al., 2018, ACP

Detecting missing sources – anthropogenic dust – using ground measurements



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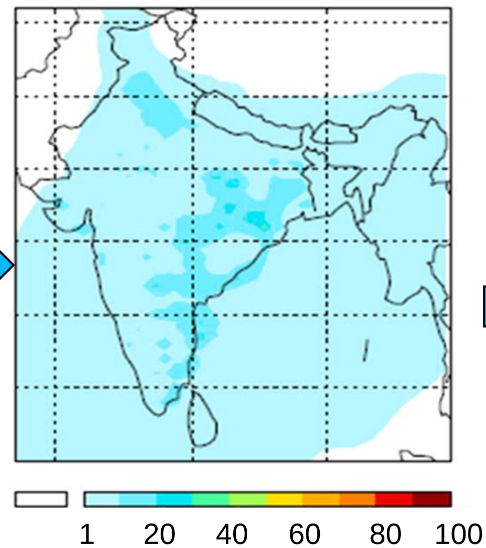
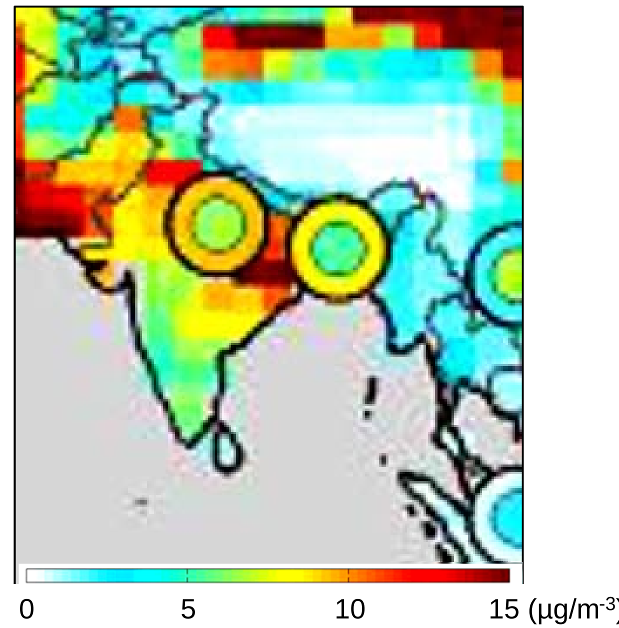


AFCID
% contribution to ambient PM2.5 conc.

Total Dust



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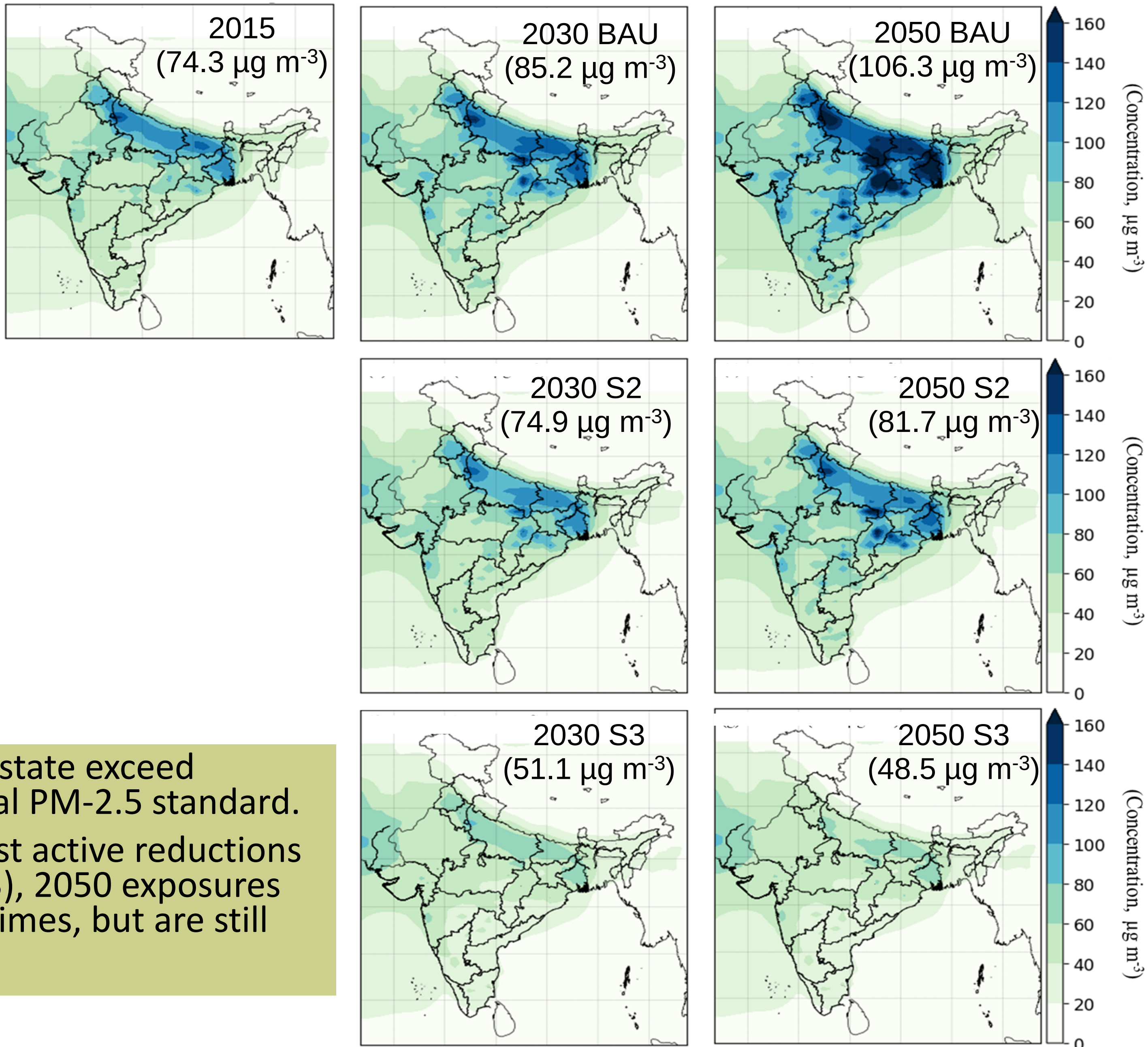
Philip, …, Venkataraman et al., 2017 ERL

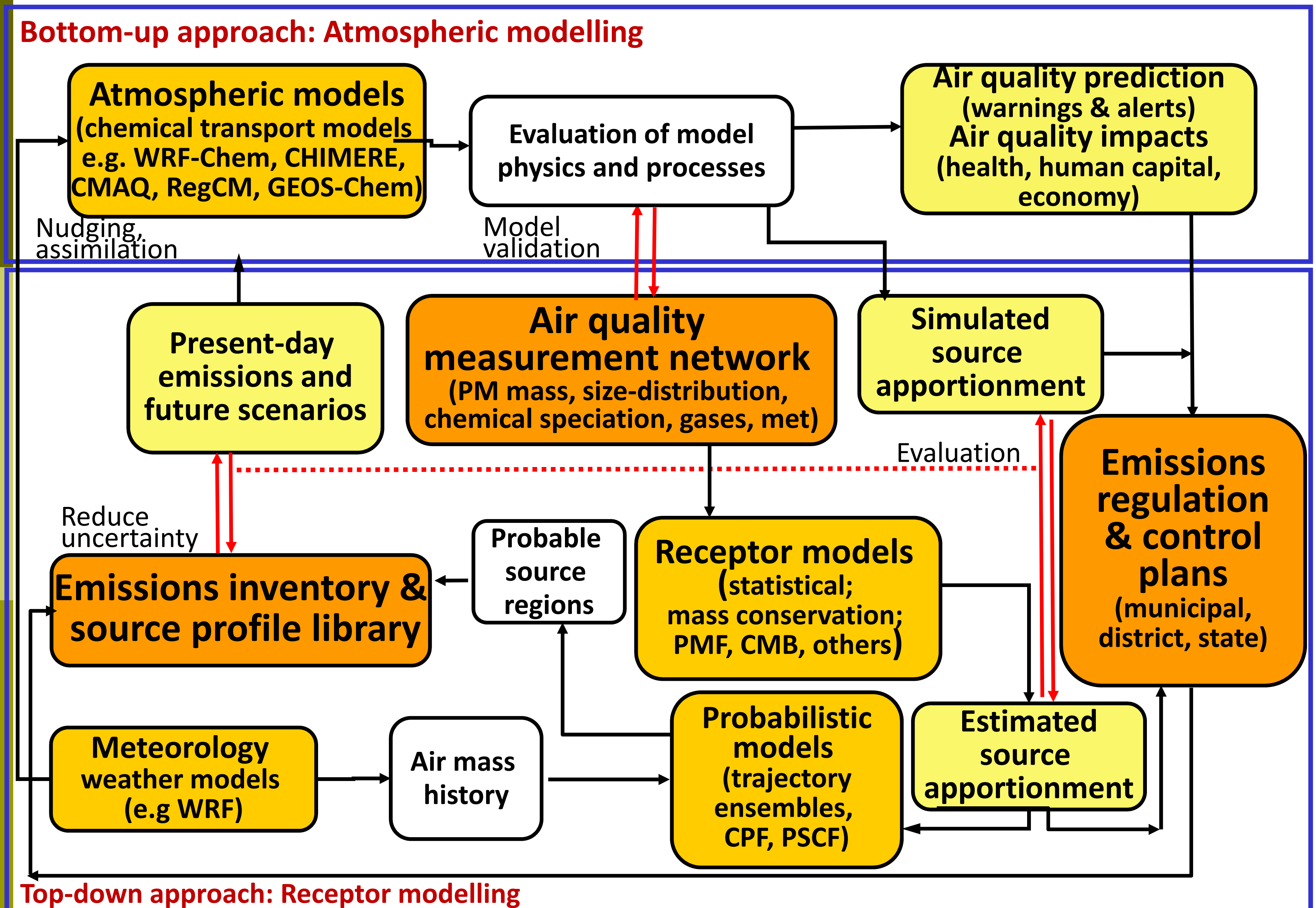
Air pollution is a pan-India problem



- In 2015, most state exceed national annual PM-2.5 standard.
- Under the most active reductions envisioned (S3), 2050 exposures drop by 1.5-2times, but are still too high.

(Venkataraman et al., 2018, ACP)

An air quality management system: what might it look like?

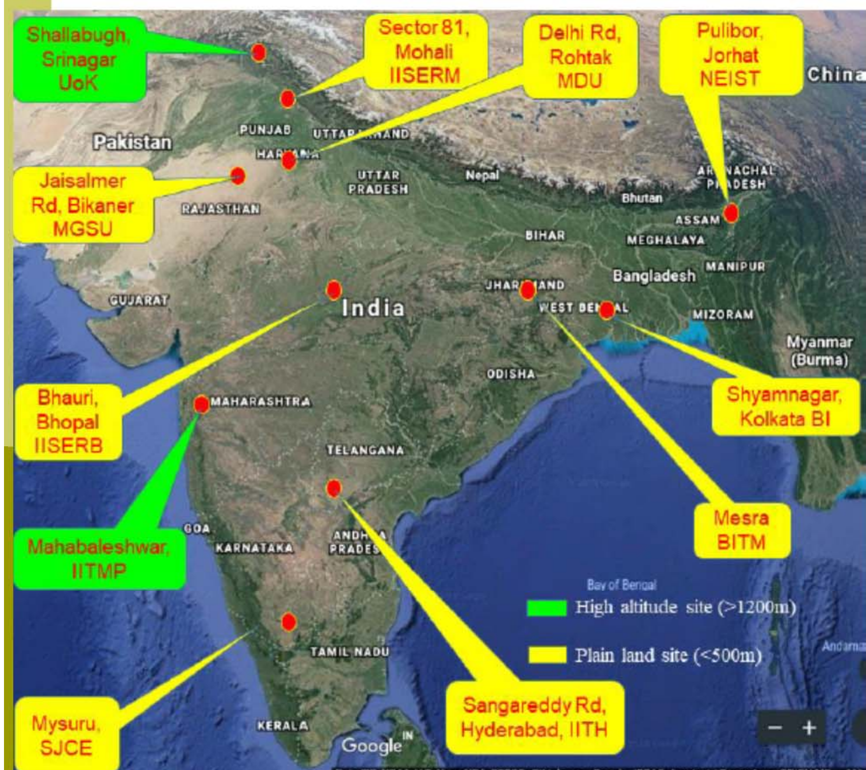


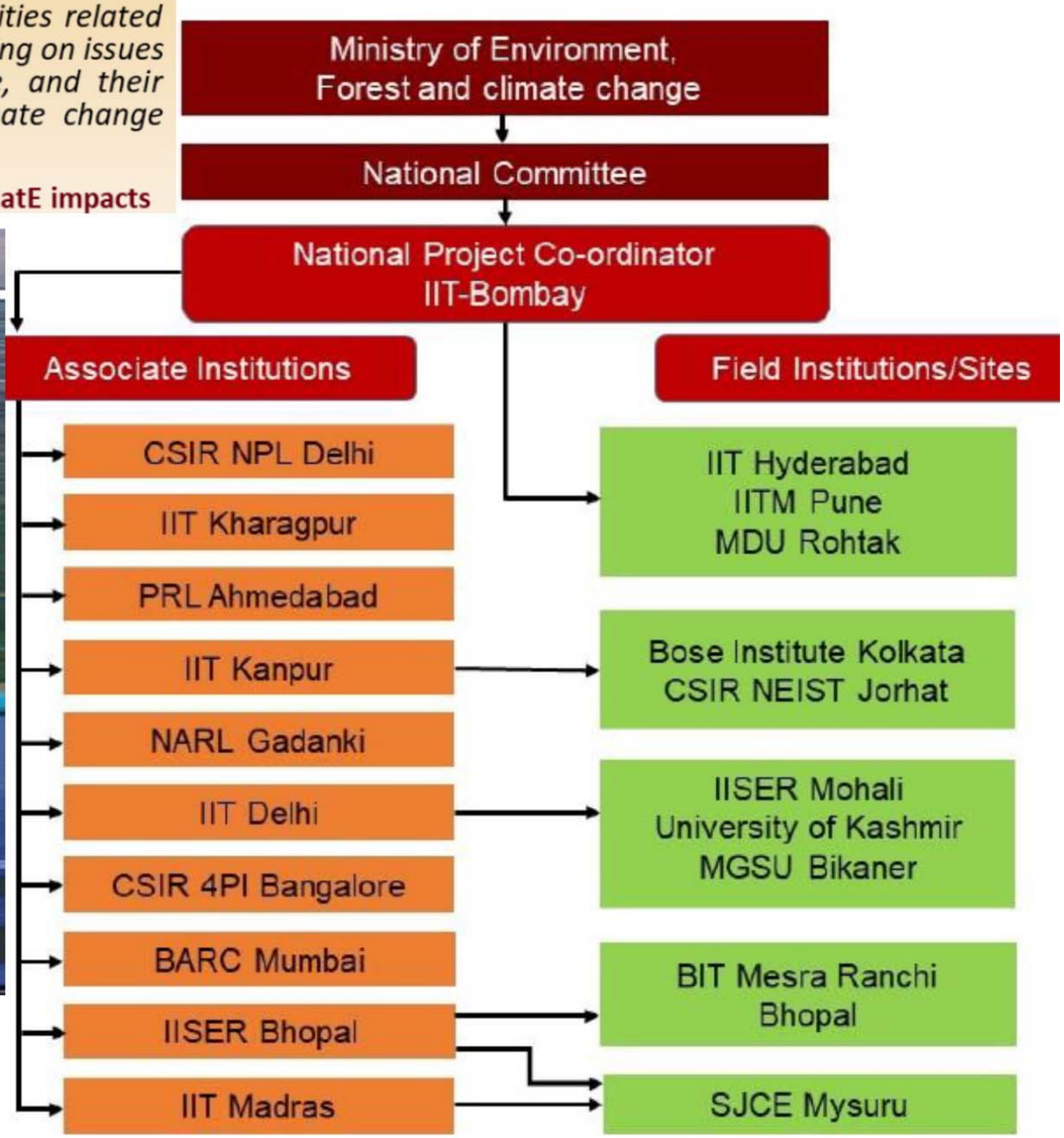
National Carbonaceous Aerosols Programme

COALESCE

Understanding scientific complexities related to carbonaceous aerosols, focussing on issues underlying their origin and fate, and their role as drivers of regional climate change over India

CarbOnaceous AerosoL Emissions, Source apportionment & ClimatE impacts





Activity-timeline of NCAP-COALESCE

2022

Linkages to India's climate and air-quality policy; decision support for climate change action.
2ND COALESCE SCIENCE WORKSHOP

2021

Chemically speciated source profile library;
Harmonized source apportionment.

Simulated source apportionment.
Climate impacts of carbonaceous aerosols.
Climate impacts and climate feedback on air quality.

2020

Receptor modelling for source apportionment.

1ST COALESCE SCIENCE WORKSHOP

2019

Observations: Extended phase (2019-2020, 24 months) and intensive phases (3-6 months);
Field campaigns: Apr, Oct-Dec, 2019 and Jan-May 2020;
Chemical speciation: ambient and source measurements;
Data centre: design and operations.

Atmospheric modelling: Multi-model intercomparison of aerosol lifecycle: 5-GCMs and 6-RCMs

2018

Regional observational network commissioning - eleven pan-India sites;
Field campaign initiation for activity and emission measurements.

2017

Regional observational network design, site selection, field campaign planning.