Climate footprint of selected Indian emission sectors

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Climate change effects have a regional character

Observed Temperature Trends (1900-1995)

IPCC-AR4, 2007
From 1981–2006, the rate of clear-sky dimming over India, attributed to aerosols, is 6 W/m²-decade. (Kumari et al., 2009, GRL).
Aerosol mediated fog events in winter

Fog blinds north India, 10 killed in train collisions

Dense Fog Conditions Force Airport To Implement Low Visibility Procedures For 16 Hours

Record at fog-hit Delhi: 54 flights cancelled

Over 50 flights cancelled as fog blankets Capital

Three die, 17 hurt in train mishap due to fog in UP

Northern Grid Trips, Flights Hit At Delhi Airport

The Times Of India Kolkata; Date: Jan 28, 2010

Mumbai Mirror; Date: Jan 17, 2010

The Times Of India Delhi; Date: Jan 28, 2010

The Times Of India Kolkata; Date: Jan 28, 2010
Outline

- What do we know about S. Asian aerosol sources?
- How good is this understanding?
- Frameworks for mitigation.
Region specific sources

- Brick kilns
- Agricultural residue burning
- Emissions from Cook stoves
- Unregulated vehicular emissions
Emission Inventory

\[ E_P = \sum_i \text{Activity}_i \times \text{Emission Factor}_{i,P} \]

**Fuel consumption/Production**

**Emissions per unit fuel consumption/Production**

**Default Emission Factors**  
(IPCC 2006, EMEP 2009)

**TIER 1**
- Average emission factors for a broad source category
- Default fuel characteristics

**TIER 2**
- Country specific details
- Fuel characteristics (like carbon content or ash content)
- Technological details

**TIER 3**
- Combustion technology
- Operating parameters
- Age of the equipment
- Pollution control equipment employed
Metrics of Climate Change

\[ \Delta C(t) = \exp(-t/b) \]

N\textsubscript{2}O : \(b=114\) years

\[ \Delta RF(t) = A \times \Delta C(t) \]

N\textsubscript{2}O : \(A=3.88 \times 10^{-13}\) Wm\(^{-2}\)kg\(^{-1}\)

Absolute global warming potential (AGWP) (IPCC 1990)
GWP values used

Metrics calculated using parameters from literature (Fuglestad et al. 2007, Bond and Sun 2005)
Creating an emissions inventory ~Tier 3 detail

Activity data
Plant wise for LPS, District level fuel use, technology/process linked emission factors

Technology/Process intervention

Thermal Power Plants

Emission factors based on fuel, process technology, APCD, operating conditions

Transport Road

Fossil Fuel

Agricultural residue burning

Open burning

Brick kilns

Emission Factor

Emissions

Appropriate Proxy

Gridded Emissions
0.25° x 0.25° resolution

Thermal power plants

Power plants – Electricity generation (CEA, 2007)
Total capacity for generation: 66 GW + 13 GW

Coal based power plants
No. of plants = 78
Plant-wise data for Power load factor & Specific fuel cons.

Oil & gas based power plants
No. of plants = 51
Plant-wise data available for fuel consumption

Fuel consumption

Emission factor based on technology (g/kg of fuel)

Plant wise control equipments used

Emissions (National level)

GWP for each pollutant

Tg/year of CO₂ equivalent
Transport sector - roadways

Category wise vehicle population (1951-2006)
National level (MoORTH)

Weibull distribution function (Category wise)

On road survived Vehicle population
(Vintage-Category wise)

Annual mileage in km
(Category wise)

Emission factor in g/km
(Vintage-Category wise)

Emissions
(National level)

GWP for each pollutant

Tg/year of CO₂ equivalent
Brick production

Fuel consumption data (Maithel, 2001)
Amount of coal consumed = 24000 kT

Kiln type specific energy consumed (MJ/kg of brick produced)

kg of bricks produced in each kiln type

BTK – fixed chimney
BTK – moving chimney
Clamps
Zig-zag firing
Vertical shaft brick kiln

Emission factor

Emissions (National level)

GWP for each pollutant

Tg/year of CO₂ equivalent
Discontinuous sources: agricultural residue burning

MODIS fire map: Oct 23, 2009

Field burning not well represented in global inventories.

Unit: kg/km² - mon
Estimated fuel consumption

Fuel consumed in selected four sectors for year 2005

Coal consumption – Thermal power plant (330 million tonne/yr)
Petroleum consumption – Road transport (53 million tonne/yr)
Biomass consumption – Agricultural residue burning (101 million tonne/yr)
Technology-linked fuel consumption

**Brick production**
- High draft/zig-zag firing: 0%
- Clamps: 22%
- BTK-Moving chimney: 29%
- BTK-Fixed chimney: 49%
- Vertical shaft brick kiln (VSBK): 0%

**Transport-roadways**
- HDDV: 73%
- CNG: 1%
- 2-Stroke petrol: 7%
- 4-Stroke petrol: 3%
- Cars petrol: 9%
- LDDV: 7%

**Thermal power plant**
- Oil fired boilers: 0%
- Gas turbine: 3%
- Coal fired boilers: 1%
- Pulvurized coal DB/WB – 96%

**Agricultural residue burning**
- Sugarcane: 28%
- Cereals: 72%
Ag. Residue burn – Mainly responsible for methane emissions
Thermal Power Plant – Major source of CO₂ due to massive consumption of fossil fuel especially coal
NOx emissions were emitted from burning of fossil fuels on large scale, i.e. transport and thermal power plants. Uncontrolled and incomplete combustions from agricultural residue burning caused higher CO emissions.
Black carbon, was highly emitted from transport sector which made the use of super-emitter vehicles fraction. SO$_2$ emissions were largely emitted from thermal power plant which consumed coal about 330 million tonnes. Organic carbon was found to be high from agricultural residue burnings.
Emissions summary – Black carbon

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<thead>
<tr>
<th>Emissions (Gg/year)</th>
<th>BC</th>
<th>OC</th>
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<tbody>
<tr>
<td>Thermal Power</td>
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<td>Transport</td>
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<td>Bricks</td>
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<tr>
<td>Agri. Burn</td>
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</tbody>
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BC Emissions (Gg/year): 302
OC Emissions (Gg/year): 397
Frameworks for mitigation

PM$_{2.5}$ Emissions (Gg/year)

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<th>GWP</th>
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<tr>
<td>BC</td>
<td>608</td>
</tr>
<tr>
<td>OC</td>
<td>-70.8</td>
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<tr>
<td>SO$_4$</td>
<td>-40</td>
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Among short-lived forcers BC was the dominant species warming the atmosphere mainly from transport. While OC from ag. residue burn and SO2 from power plant showed negative effect.
Conclusions

- Sectoral methodologies are developed for energy use and emissions estimation.
- Technology-linked emissions estimation is needed for accurate magnitudes of total and sectors emissions.
- Short-lived forcers offer two important benefits: air-quality and health mitigation, immediate reduction in atmospheric warming (in the near term).
- Among sectors considered, diesel transport, agricultural residue burning and brick production offer mitigation potential based on short-lived forcers.
- Frameworks based on multiple criteria allow mitigation strategies which offer simultaneous benefits for air quality and climate.
THANK YOU