Quantifying the contribution of Long-Range Transport to Particulate Matter (PM) loading at a suburban site in the North-Western Indo-Gangetic Basin

THE SECOND WORKSHOP ON ATMOSPHERIC COMPOSITION AND THE ASIAN SUMMER MONSOON (ACAM)

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INDIA
Sinha et al., Chemical composition of pre-monsoon air in the Indo-Gangetic Plain measured using a new air quality facility and PTR-MS: high surface ozone and strong influence of biomass burning., Atmos. Chem. Phys., 14, 5921–5941, 2014
Requests for data are welcome
Please send an e-mail to: vsinha@iisermohali.ac.in
Indo-Gangetic Basin

Global Annual Average PM$_{2.5}$ Grids from MODIS 2010

**Health Impacts**
- Direct impacts
- Indirect impacts

**Environmental Impacts**

- Elevated PM Levels
- Number of exceedance events

**Quantitative Contribution of Long-Range Transport**

**PM$_{10}$**: 100 µg/m$^3$ (24 hour average)

**PM$_{2.5}$**: 60 µg/m$^3$ (24 hour average)

**NAAQS**

**PM$_{10}$**: 100 µg/m$^3$ (24 hour average)

**PM$_{2.5}$**: 60 µg/m$^3$ (24 hour average)

**Health Impacts**
- Impacts on Central Nervous System
- Cardiovascular Diseases
- Respiratory Disorders
- Impact on Reproductive System

**Health Impacts**

**Environmental Impacts**

**Elevated PM Levels**

**Number of exceedance events**

**Quantitative Contribution of Long-Range Transport**

**NAAQS**

**PM$_{10}$**: 100 µg/m$^3$ (24 hour average)

**PM$_{2.5}$**: 60 µg/m$^3$ (24 hour average)
Periods of calm (Wind Speed < 1ms$^{-1}$) and periods of rapid transport of air masses (Wind Speed > 5ms$^{-1}$) are highlighted in the wind-rose plots for the period of August 2011 to June 2013. Calm conditions account for < 9% in all seasons. North-west or south-east is the dominant wind direction. Rapid transport of air masses occurs frequently.
Diel Features of Particulate Matter (PM): Winter Season

Local sources like traffic and biomass combustion dominant

Least contribution from local sources

Maximum daytime boundary layer height (~1.5 to 2km)
Back Trajectory Cluster Analysis

- **k-means clustering**

Computed three day (72h) back trajectories using HYSPLIT_4

August 2011-June 2013
Arrival time 09:00 UTC and 23:00 UTC

IISER Mohali Atmospheric Chemistry Facility
(30.67°N, 76.73°E; 310 m amsl)

Back-Trajectory Cluster Analysis
k-means clustering

### PM$_{2.5}$ vs Local Time of the Day (UTC + 5:30)

- **Coarse mode PM**
- **Fine mode PM**

03:00 to 06:00 LT
Least contribution from local sources

12:00 to 16:00 LT
Maximum daytime boundary layer height (~1.5 to 2km )
**Westerly (Fast, Medium, Slow & South-west)**

- **Source**: Middle east, Arabia, Afghanistan and Thar desert
- > 35% in winter, summer and post-monsoon

**South-Easterly Transport**

- Synoptic scale transport: western disturbance in summer and winter
- Bay of Bengal branch of monsoon

**Local**

- Synoptic scale transport over NW-IGP
- > 30% in all seasons
- Represents the regional background

**Calm Conditions (WS < 1ms⁻¹)**

- Local sources
- < 9% in all seasons
Impact of Wet Scavenging on Particulate Matter (PM) Loading

Wet scavenging had a profound impact in lowering the levels of both PM$_{10-2.5}$ and PM$_{2.5}$ for all clusters associated with rain events.

In some cases where convection dust storms accompanied rain event, increase in average cluster loading observed.
Impact of Air Mass Transport on Particulate Matter (PM) Loading

Coarse mode PM

![PM10-2.5 (µg m⁻³)]

- Winter (Dec-Feb)
- Summer (Mar-Jun)
- Monsoon (Jul-Sep)
- Post-Monsoon (Oct-Nov)

![Fast Westerly](image1)
![Medium Westerly](image2)
![South Westerly](image3)

Pawar, H., Garg, S., Kumar, V., Sachan, H., Arya, R., Sarkar, C., Chandra, B. P., and Sinha, B.: Quantifying the contribution of long-range transport to Particulate Matter (PM) mass loadings at a suburban site in the North-Western Indo Gangetic Plain (IGP), Atmos. Chem. Phys. Discuss., 15, 11409-11464
Impact of Air Mass Transport on Particulate Matter (PM) Loading

Fine mode PM

January 20, 2015 20:00 LT

February 1, 2015 18:30 LT

February 7, 2015 19:30 LT
Impact of Air Mass Transport on Particulate Matter (PM) Loading

Enhancement (in %) of PM mass loadings above the levels observed for the “Local” cluster

<table>
<thead>
<tr>
<th>PM&lt;sub&gt;10-2.5&lt;/sub&gt;</th>
<th>Fast Westerly</th>
<th>Medium Westerly</th>
<th>Slow Westerly</th>
<th>South Westerly</th>
<th>South Easterly</th>
<th>Calm</th>
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<tbody>
<tr>
<td>Winter</td>
<td>18</td>
<td>28</td>
<td>22</td>
<td>9</td>
<td>Negative</td>
<td>14</td>
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<tr>
<td>Summer</td>
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<td>27</td>
<td>34</td>
<td>34</td>
<td>Negative</td>
<td>Negative</td>
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<tr>
<td>Monsoon</td>
<td>29</td>
<td>31</td>
<td>9</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Post-Monsoon</td>
<td>27</td>
<td>31</td>
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<tbody>
<tr>
<td>Winter</td>
<td>Negative</td>
<td>7</td>
<td>13</td>
<td>Negative</td>
<td>Negative</td>
<td>22</td>
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<tr>
<td>Summer</td>
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<td>4</td>
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<td>10</td>
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<tr>
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<td>Negative</td>
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</tbody>
</table>

- Fast Westerly
- Medium Westerly
- Slow Westerly
- Local
- South Westerly
- South Easterly
- Calm
Enhancement (in %) of PM mass loadings above the levels observed for the “Local” cluster

### Coarse mode PM

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<th>Season</th>
<th>Fast Westerly</th>
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### Fine mode PM

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<tr>
<th>Season</th>
<th>Fast Westerly</th>
<th>Medium Westerly</th>
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<th>South Westerly</th>
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At RH > 70%, aqueous phase oxidation of gas-phase precursors, results in high degree of correlation between coarse PM and CO (r = 0.55).

At RH < 50%, locally suspended and transported dust contribute to coarse PM.
Work In Progress: PMF Model applied to ambient data of Aug 2011 - June 2013

Factor Contribution of PM$_{10-2.5}$

- Biomass burning (BB)
- Trash and traffic (TT)
- Aqueous phase (AP)
- Dust (D)
- Photochemistry (PC)
- Industrial (IN)

81.8% D

0.9% BB
8.0% AP
0.3% Other

Courtesy: Kriti Kamal Gupta
IISER Mohali
Impact of Air Mass Transport on Particulate Matter (PM) Exceedance Events

24 hour average of PM$_{2.5}$ > 60 µg/m$^3$: EXCEEDANCE

Increase in exceedance days due to long range transport varied between a few % to at most 30%

Exceedance days controlled by long range transport to less degree.

Regional Pollution Sources
Dominant regional pollution sources contributing to PM$_{2.5}$

PM$_{2.5}$ mass loadings largely controlled by combustion sources during all seasons.

Regional pollution sources to be targeted in order to bring PM mass loadings in compliance with air quality standards.
Work In Progress: PMF Model applied to ambient data of Aug 2011 - June 2013

Factor Contribution of PM$_{2.5}$

- Biomass burning (BB) 67.0%
- Trash and traffic (TT) 4.7%
- Aqueous phase (AP) 3.9%
- Dust (D) 20.0%
- Photochemistry (PC) 4.2%
- Industrial (IN) 0.3%

Courtesy: Kriti Kamal Gupta
IISER Mohali
Long range transport from west leads to significant enhancements in average coarse (9 to 57%) and fine (4% to 31%) PM loadings in all seasons.

South-easterly air masses were the cleanest and had significantly low loadings of coarse (6 to 75%) and fine (38 to 67%) PM in all seasons.

High degree of correlation with CO (a combustion tracer) suggests most fine PM originated from combustion sources.

To bring PM mass loadings in compliance with NAAQS, mitigation of regional pollution sources needs to be given highest priority.
Acknowledgement

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ICIMOD

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DST Inspire Fellowship & IISER Mohali

Dr. Bärbel Sinha