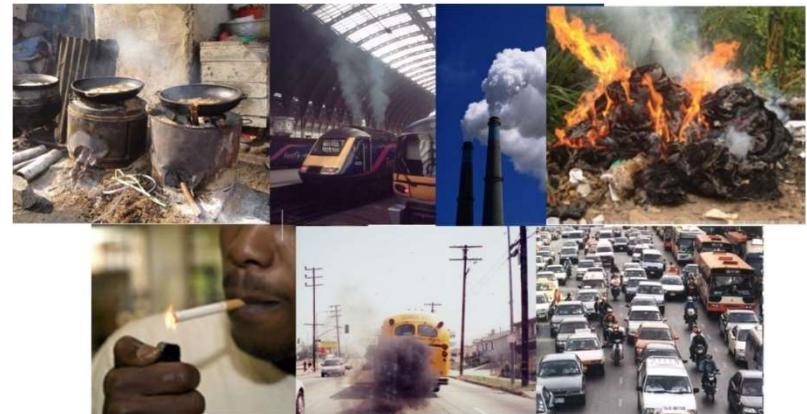
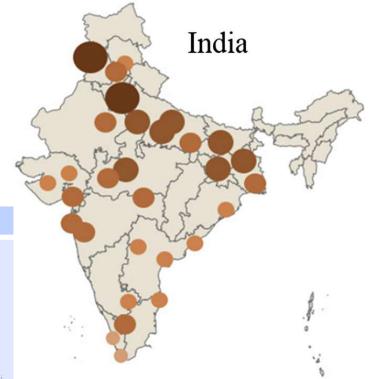
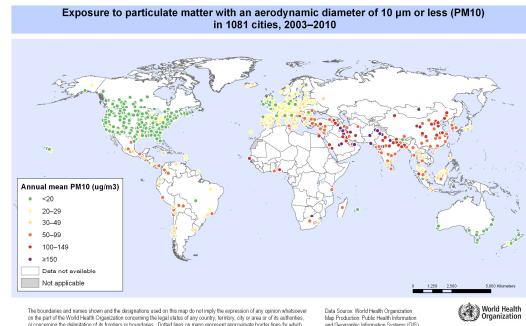


Lecture 2 Air Quality: Sources & Distribution

Harish C. Phuleria
CESE, IIT Bombay

Email: phuleria@iitb.ac.in

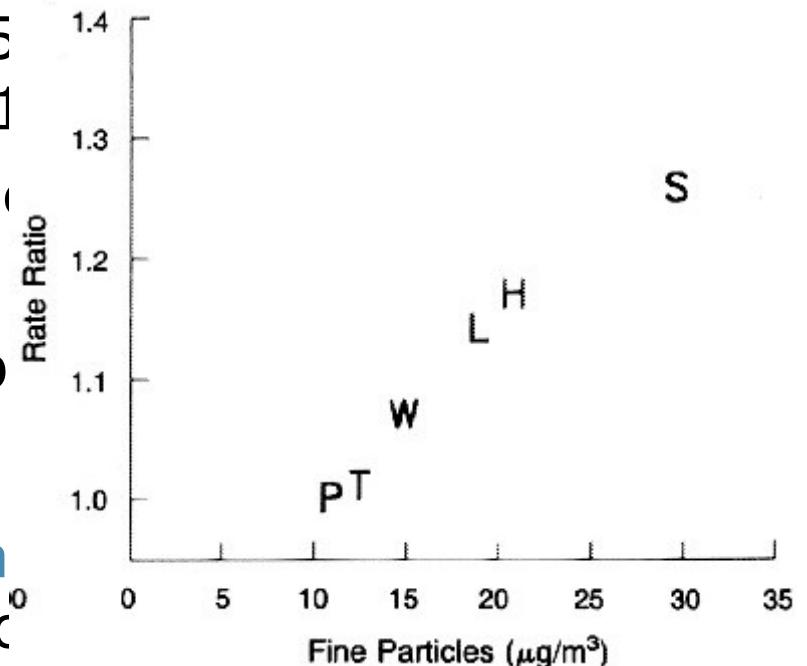


Recap 1

- Air pollution affects:
 - Human health – acute effects and chronic effects
 - Climate – direct effects and indirect effects
 - Visibility (reduced visibility mostly due to fine particles)
- Ozone is photochemically produced;
 - good in stratosphere (blocking UV radiation),
 - bad in troposphere (causing respiratory illness)
- 1952 London smog: coal power plant emissions, trapping of pollutants in winter, >4,000 deaths in a week

Recap 2

- Harvard six cities study: prospective cohort study (1974-1991) of effect of air pollution on mortality in six US cities
- One of the first studies to show linear positive association of fine PM with mortality
- Global burden of air pollution: 5 million deaths due to air pollution worldwide in 2016
- India accounts ~1/4th of total deaths
 - from household air pollution
 - from ambient air pollution (power plants, transportation, open burning)
- The Air Act, 1981; Six criteria air pollutants established:
CO, NO₂, SO₂, O₃, PM_{2.5}, PM₁₀, Pb



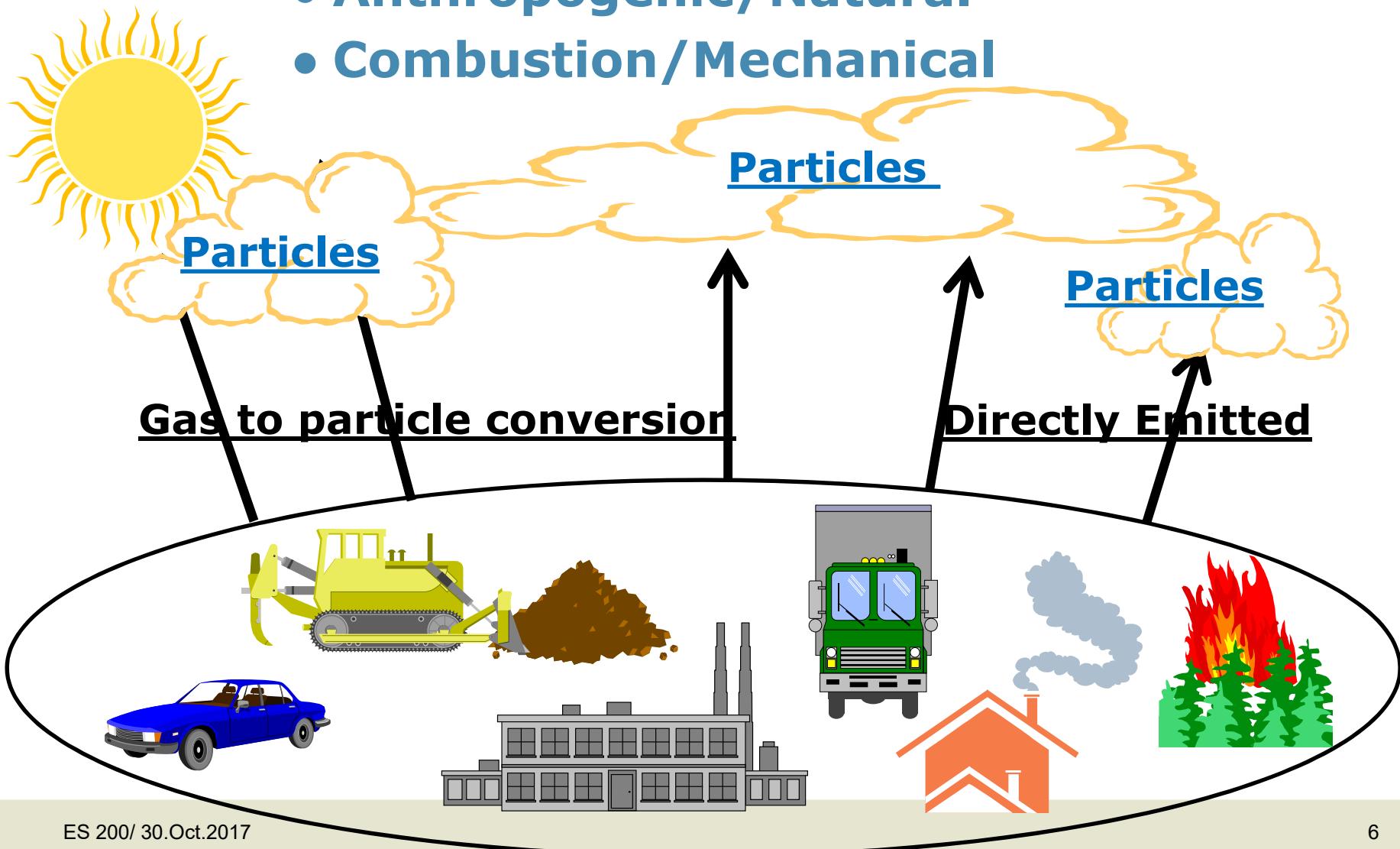
Today's Learning Objectives !

- To understand sources of air pollutants & their spatial and temporal variability
- To understand particle composition & size distribution

**Where did you last experience an
air pollution problem ???**

Sources of air pollutants

- Primary/Secondary
- Anthropogenic/Natural
- Combustion/Mechanical

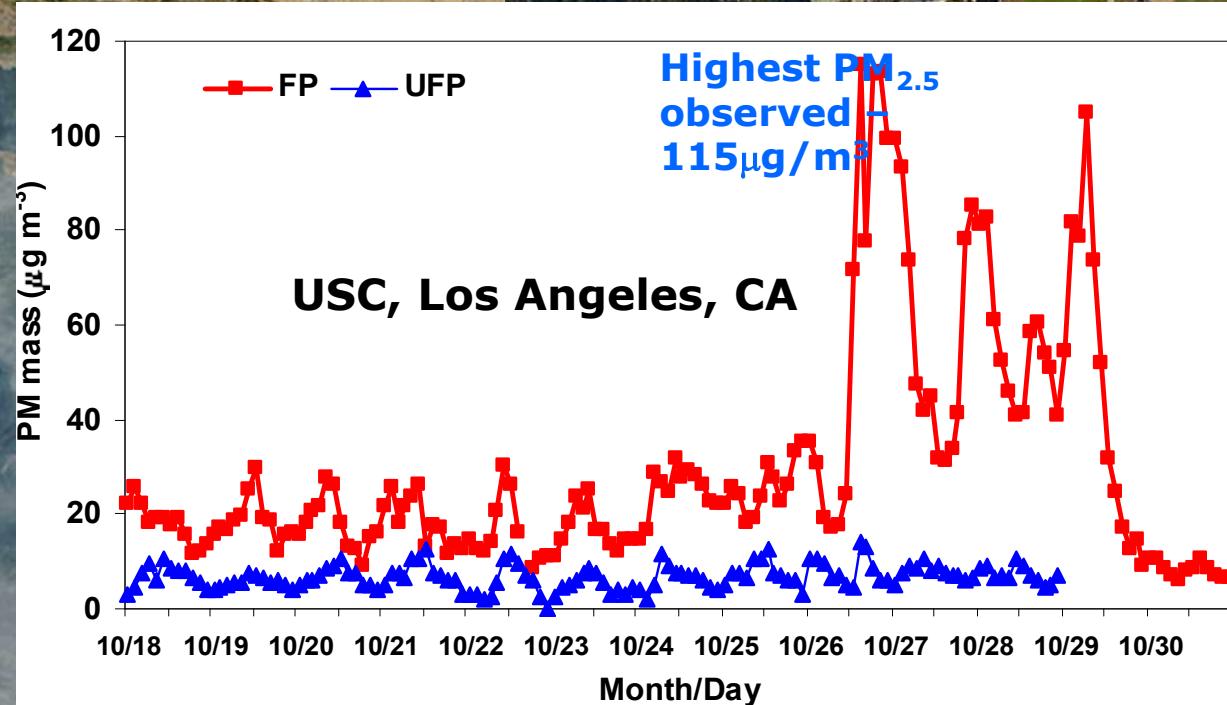
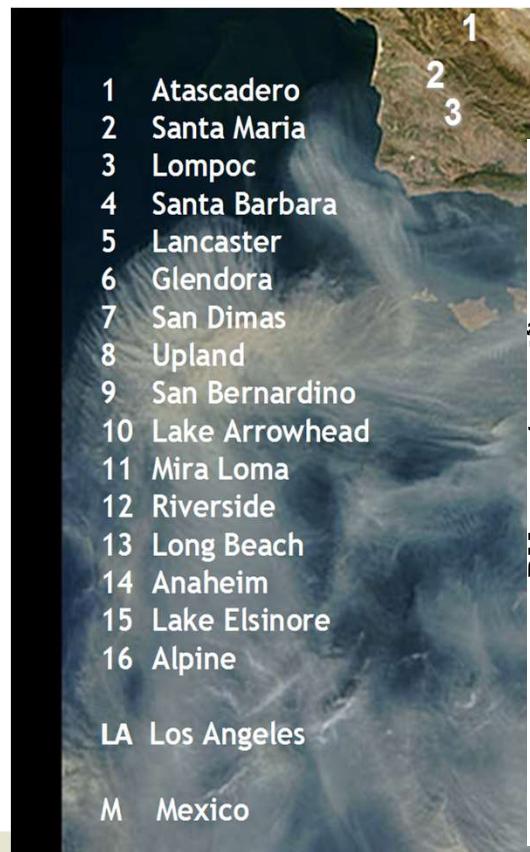


Anthropogenic air pollution sources

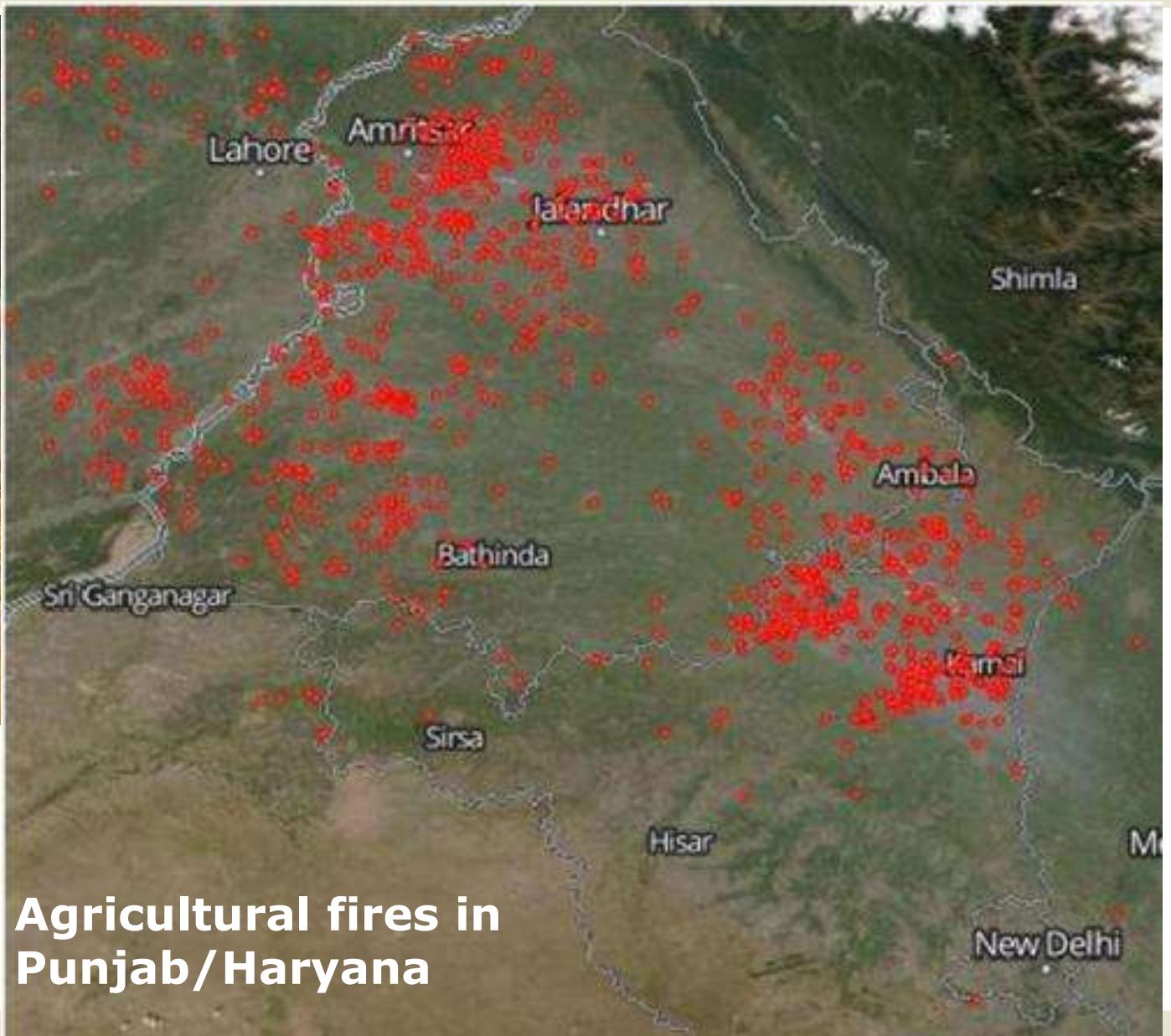


Natural sources: Wildfires

Southern California wildfires Oct 2003



Prescribed fires (anthropogenic)



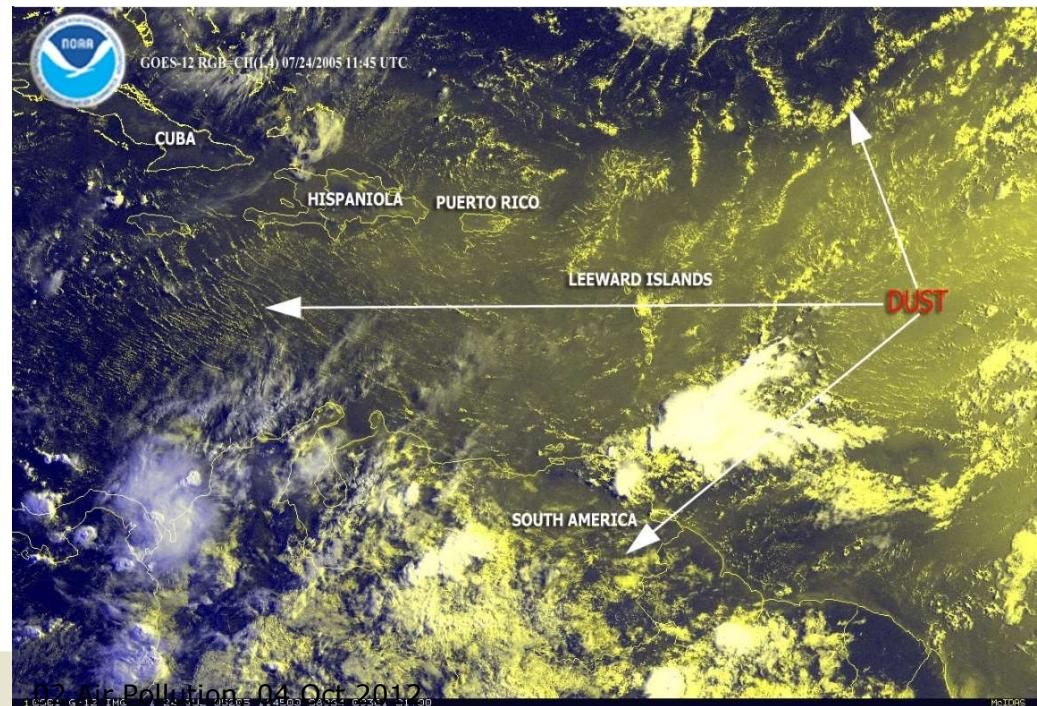
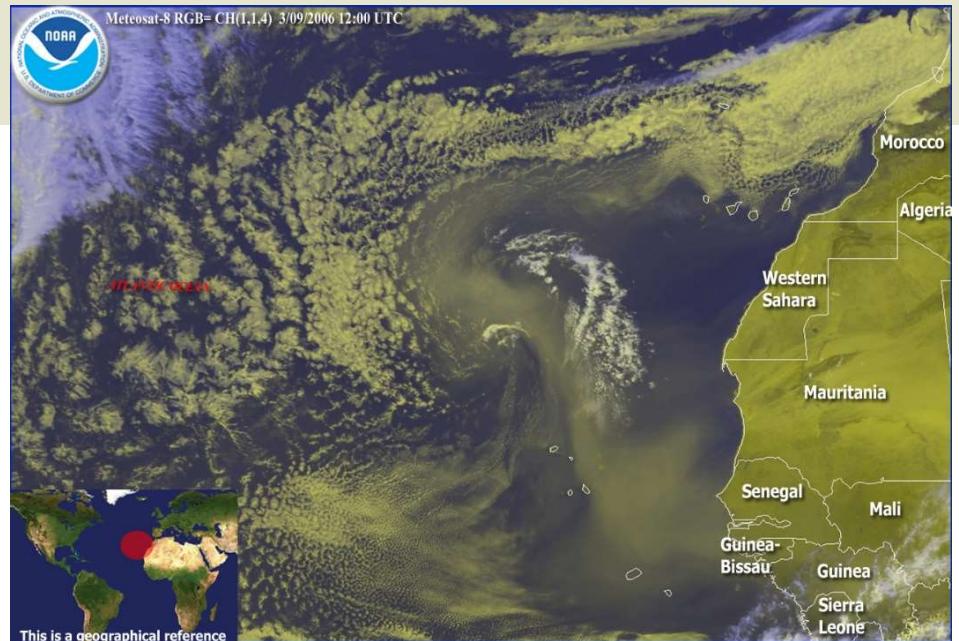
Agricultural fires in
Punjab/Haryana

ES 200 / 30 Oct 2017

<http://www.downtoearth.org.in/news/crop-burning-punjab-haryana-s-killer-fields-55960>

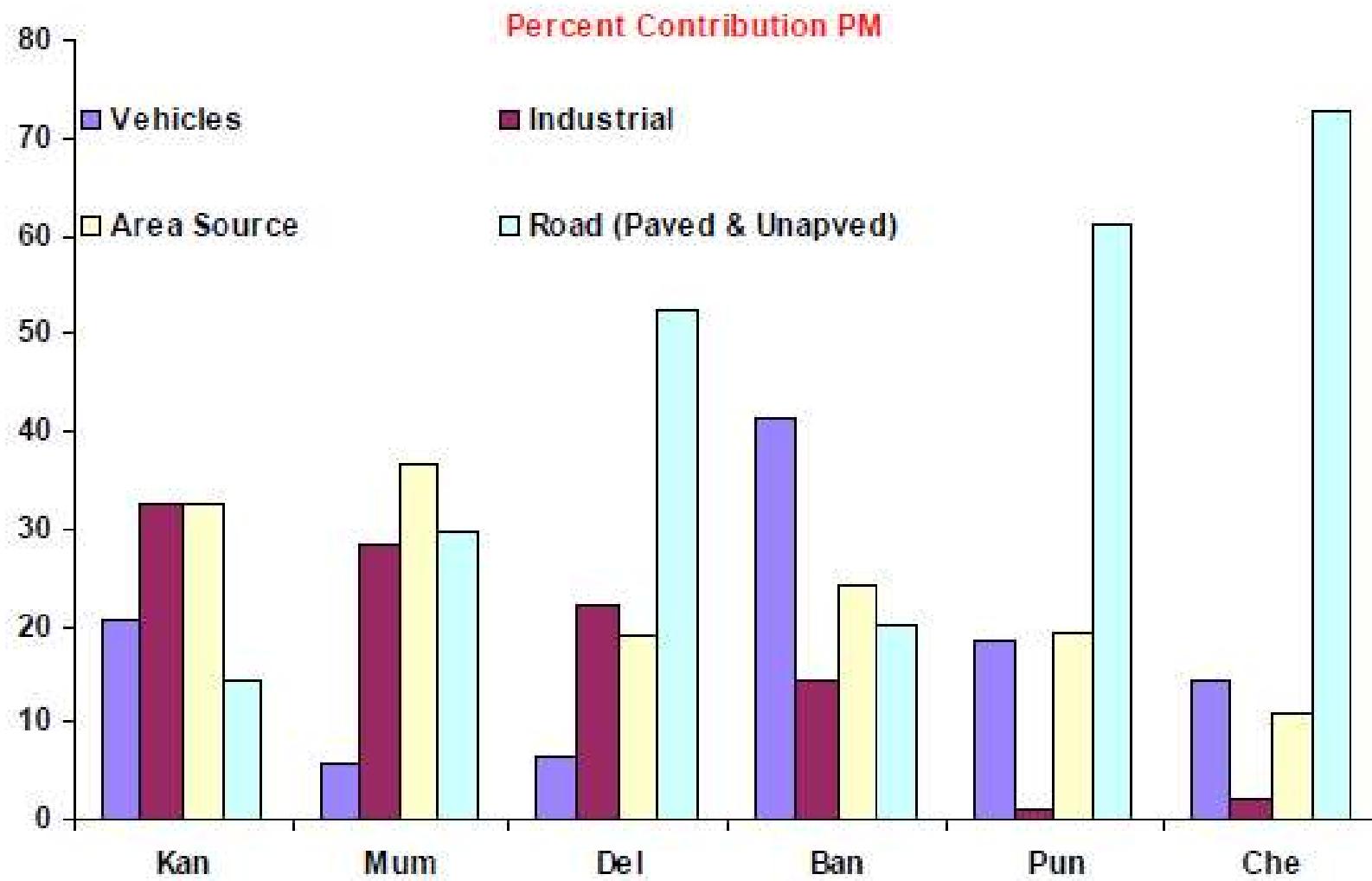
Natural sources: Wind-blown dust

**Image taken at 12:00 UTC. Large dust storm blowing off the NW coast of Africa
(NOAA, 2006)**

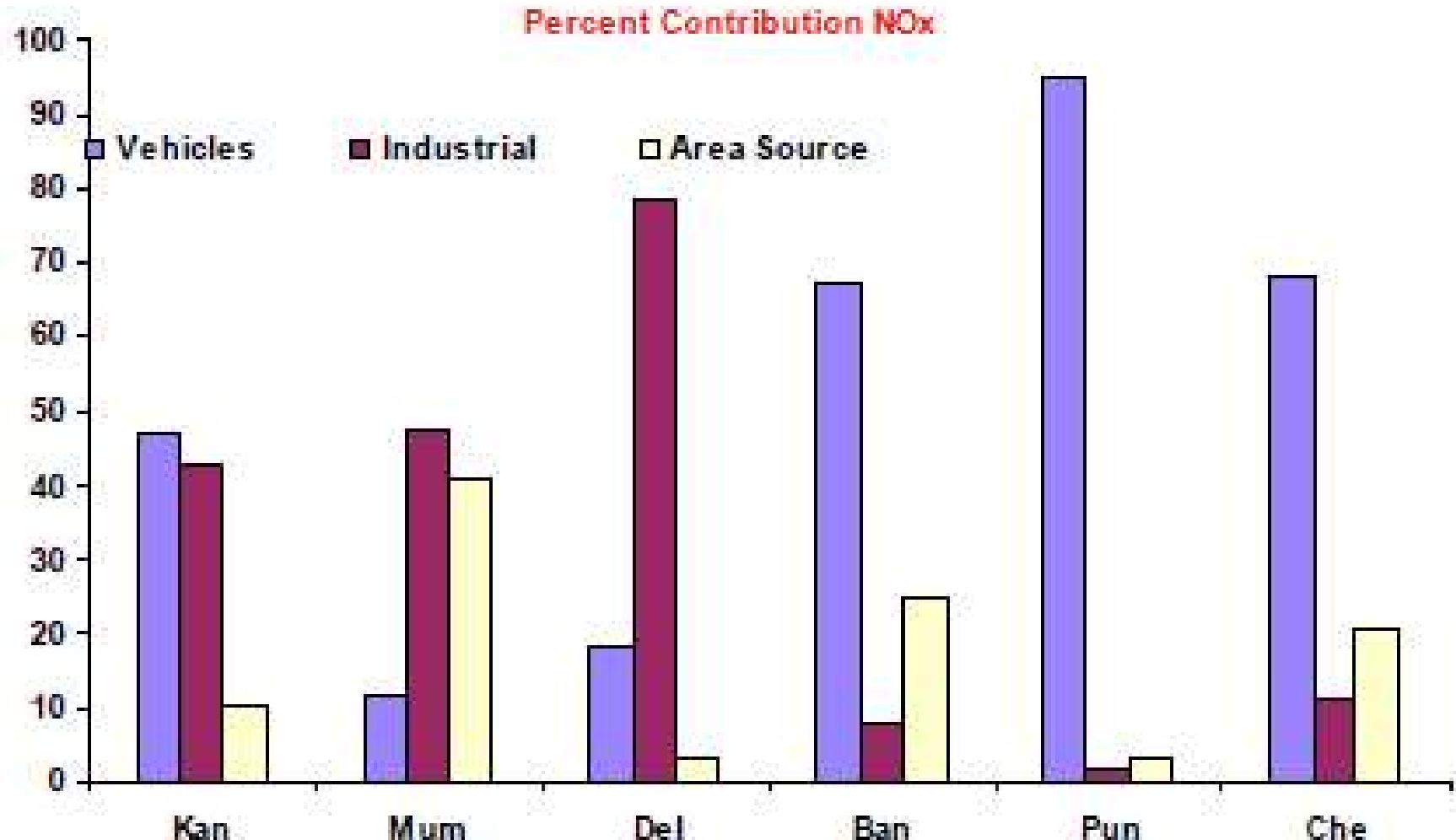


**Image taken at 7:45 EDT. Saharan dust stretching from Atlantic ocean westward; appears as yellowish brown hue and can cause hazy conditions later
(NOAA, 2005)**

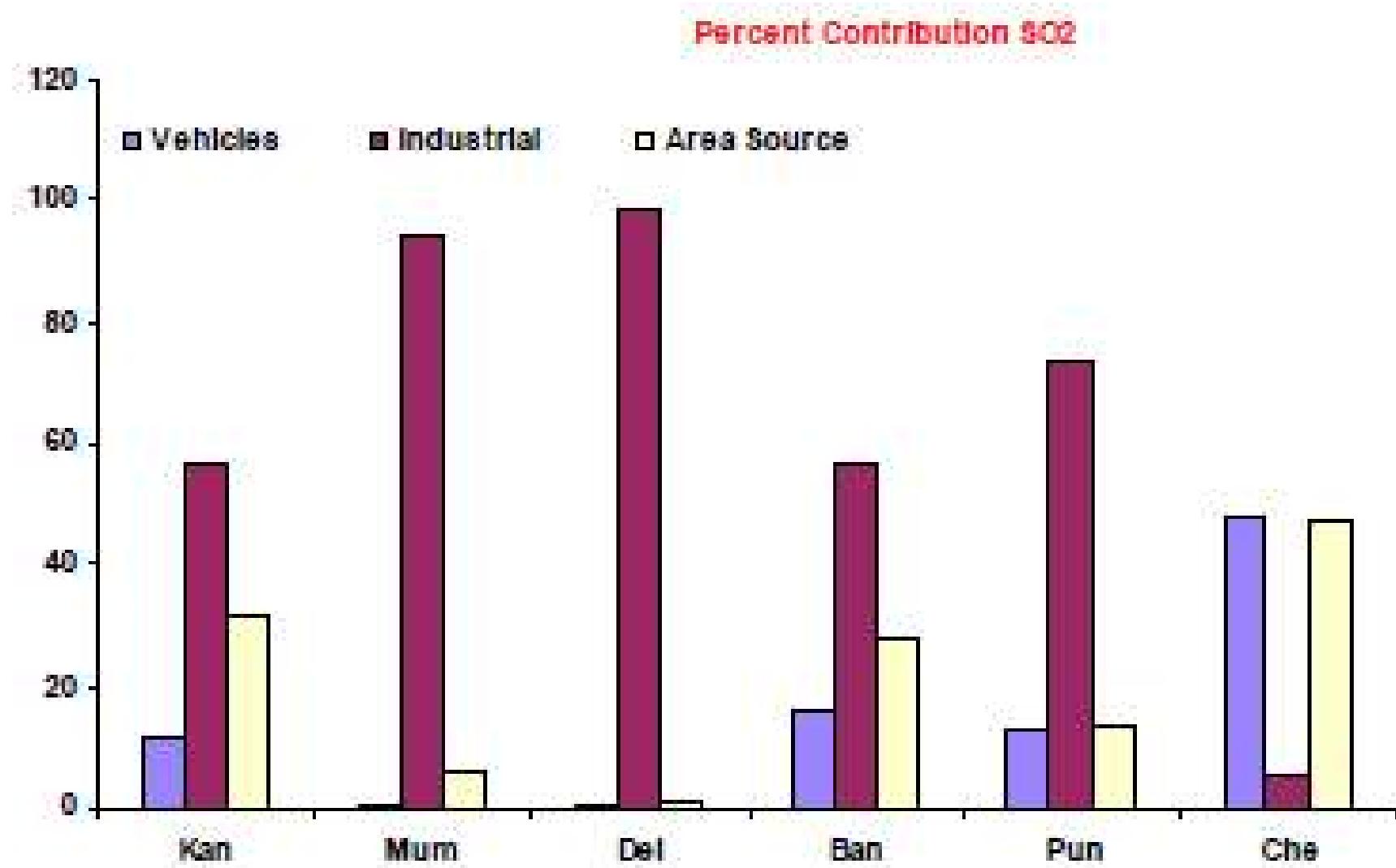
Sources of PM₁₀ in Indian cities



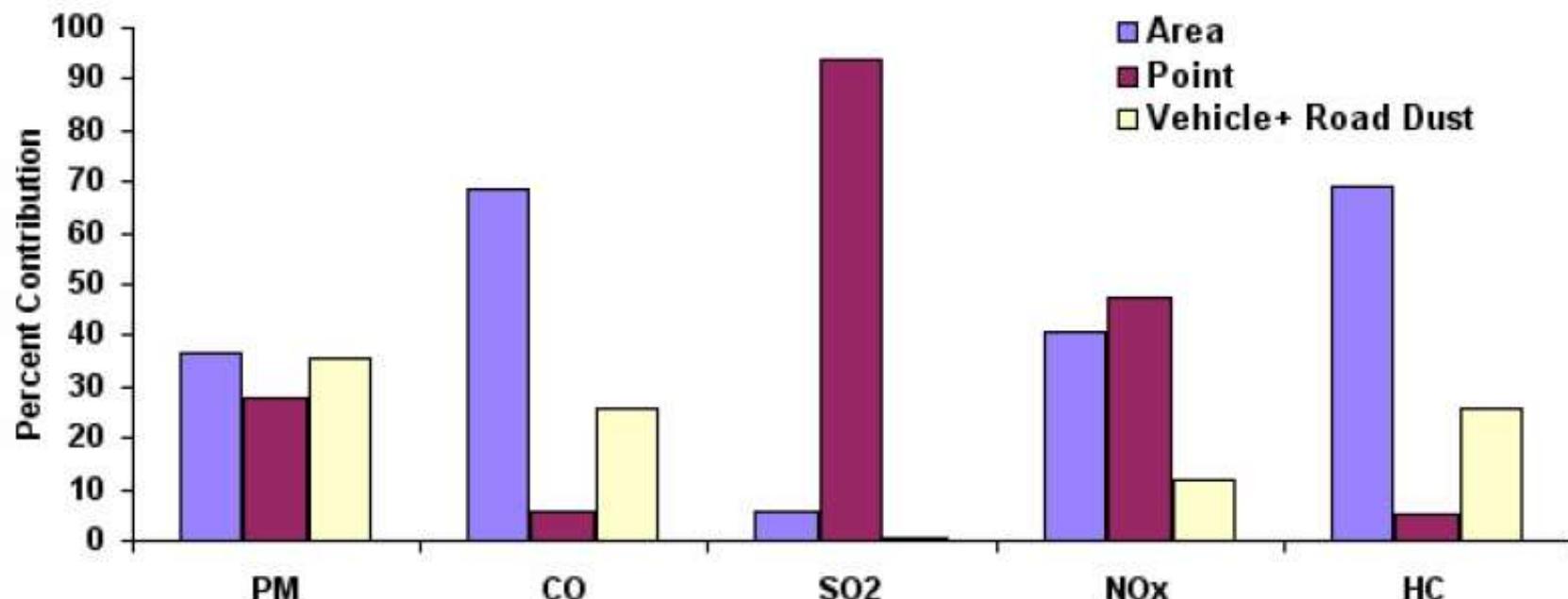
NO_x sources in Indian cities



SO₂ sources in Indian cities



Air pollution sources in Mumbai



a) Area Source

Bakeries
Crematoria
Open eat outs
Hotel restaurants
Domestic sector
Open burning
Landfill Open Burning
Construction Activity
Locomotive
(Cen.+ Wes. Rly)
Aircraft
Marine vessels

B) Industrial Source

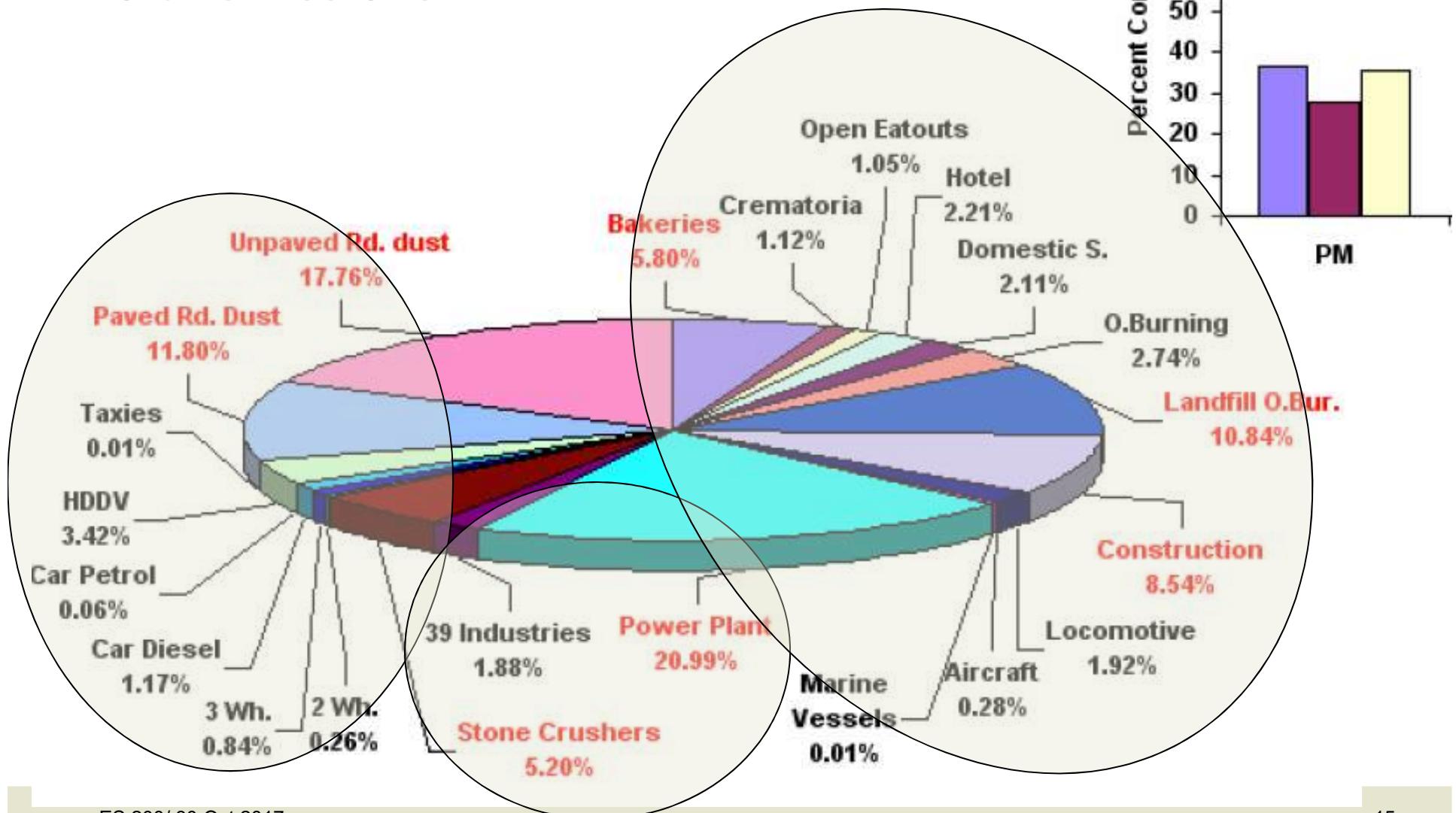
Power plant
39 Industries
Stone crushers

C) Line Source

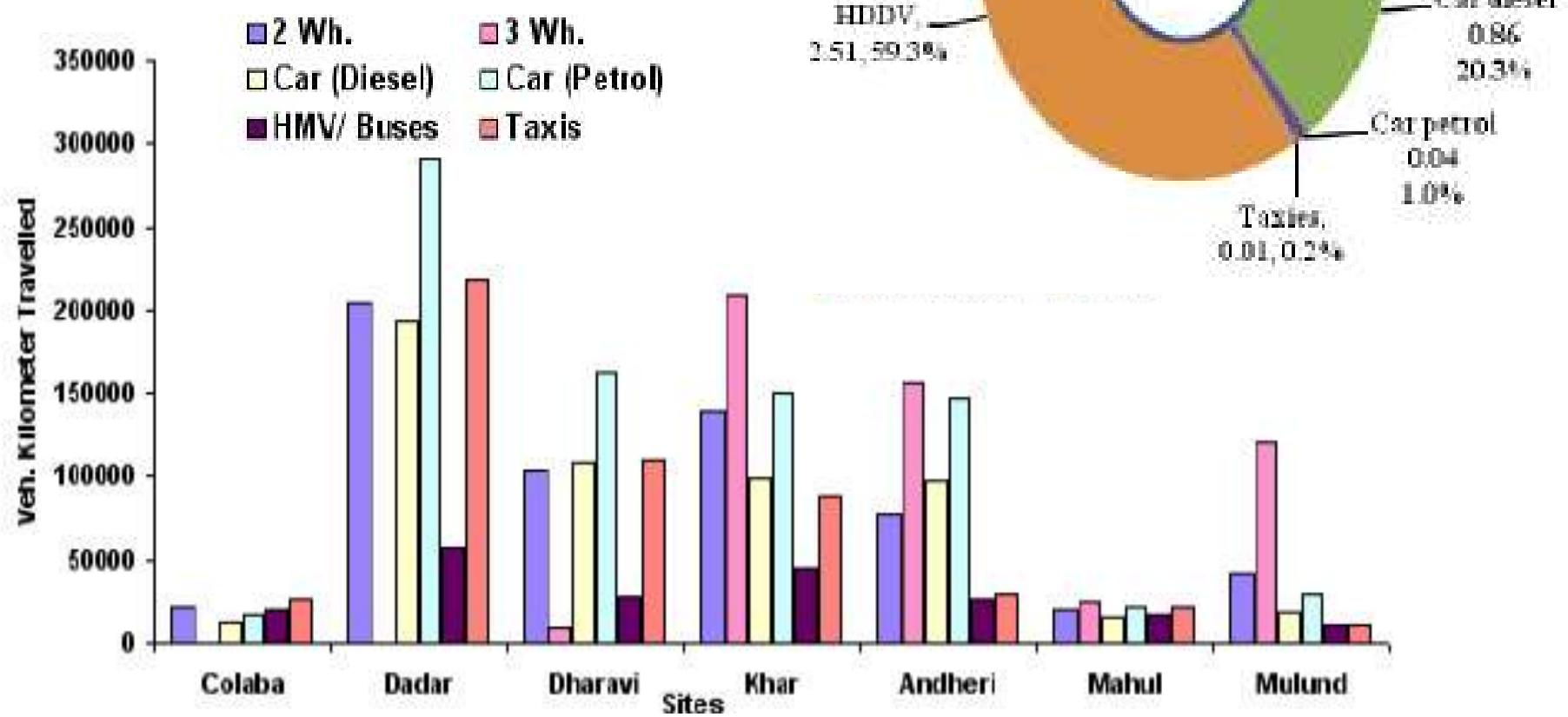
2 wheelers
3 wheelers
Car diesel
Car petrol
HMV
Taxies
Paved Road dust
Unpaved Road dust

PM₁₀ sources in Mumbai

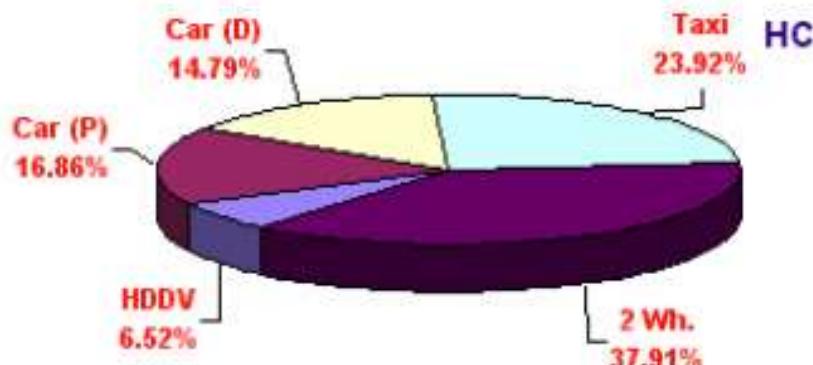
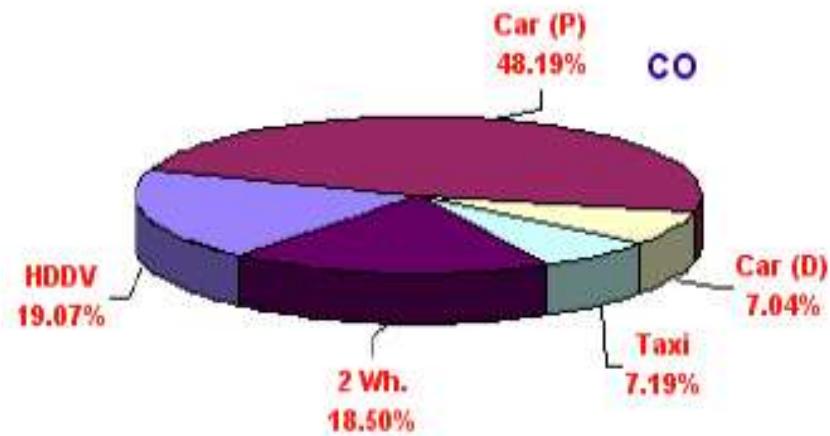
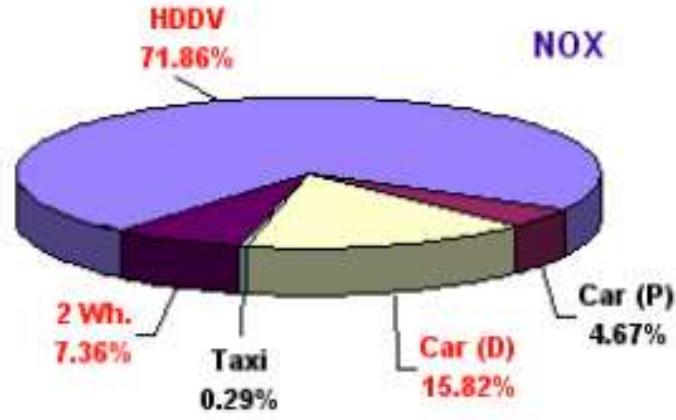
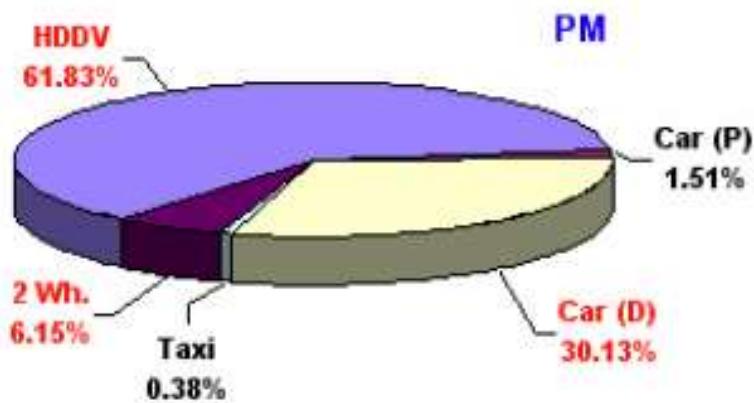
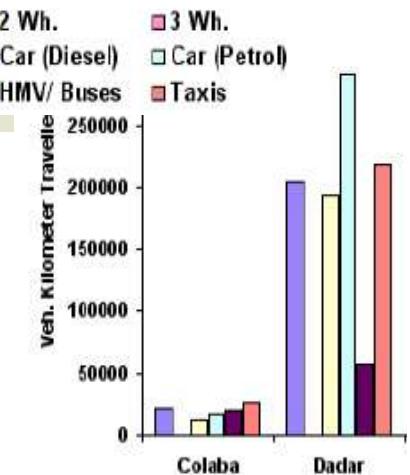
Source attribution based on total emissions



PM₁₀ vehicular sources in Mumbai



PM₁₀ vehicular sources in Dadar, Mumbai



Indoor air pollutants and sources

- Criteria pollutants – e.g. CO, NO₂ and PM_{2.5} (cookstoves and heater smoke)
- Asbestos (from old building material)
- Radon
- Household chemicals (e.g. detergents and household cleaners, aerosol sprays, shoe polish, paints, glues etc.)
- Cigarette smoke or ETS
- Outdoor pollutants infiltrating indoors



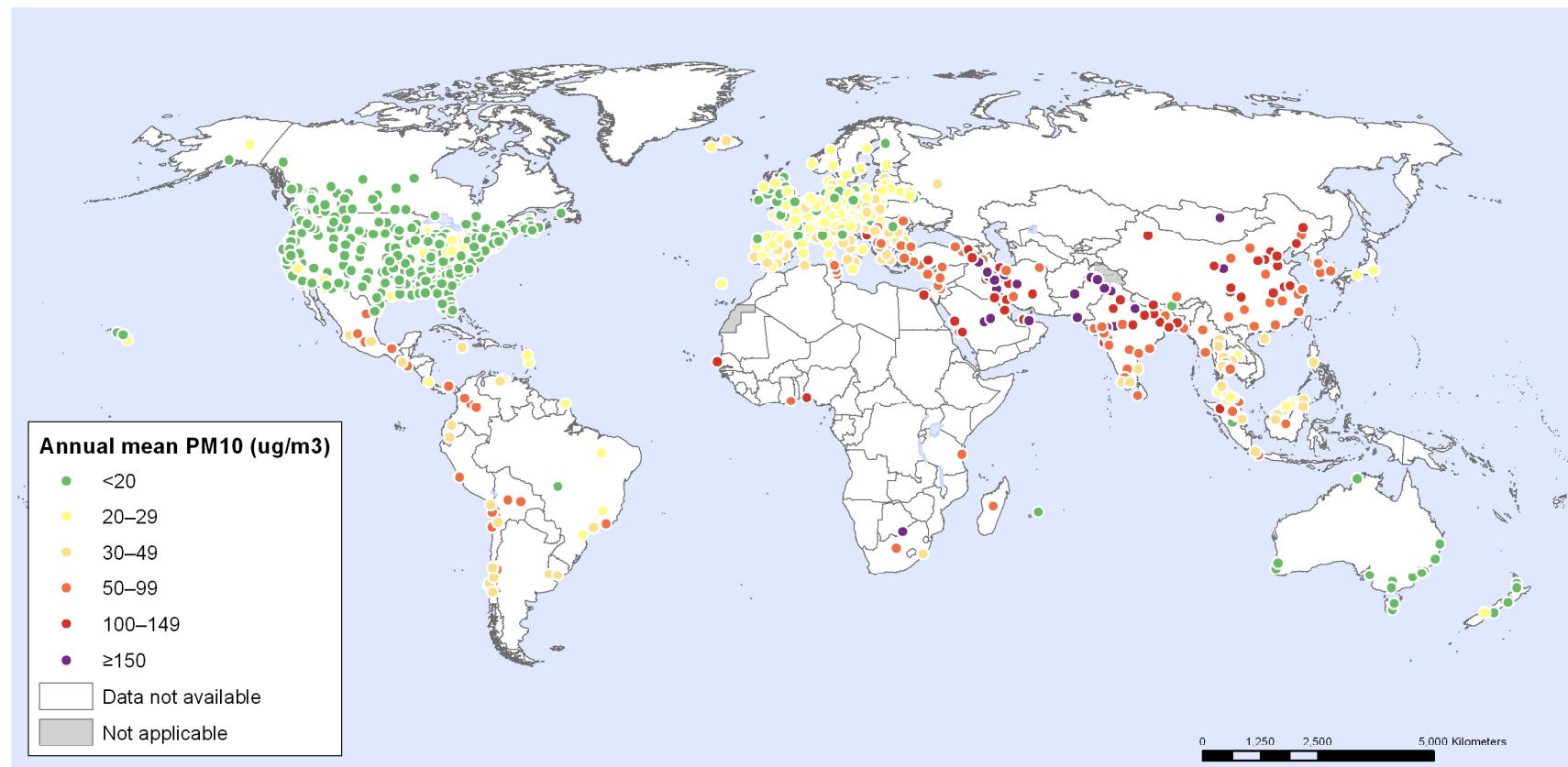
Spatial and Temporal distribution

- **Spatial variation** – on which scale?
 - local urban area/city level
 - state or national level
 - regional or global level
- **Temporal variation** – again on what time resolution?
 - hourly basis
 - daily basis
 - weekday basis
 - seasonal basis
 - annual basis
 - diurnal basis

Outdoor PM₁₀ distribution across the globe

Spatial distribution on global scale

Exposure to particulate matter with an aerodynamic diameter of 10 µm or less (PM10)
in 1081 cities, 2003–2010



The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

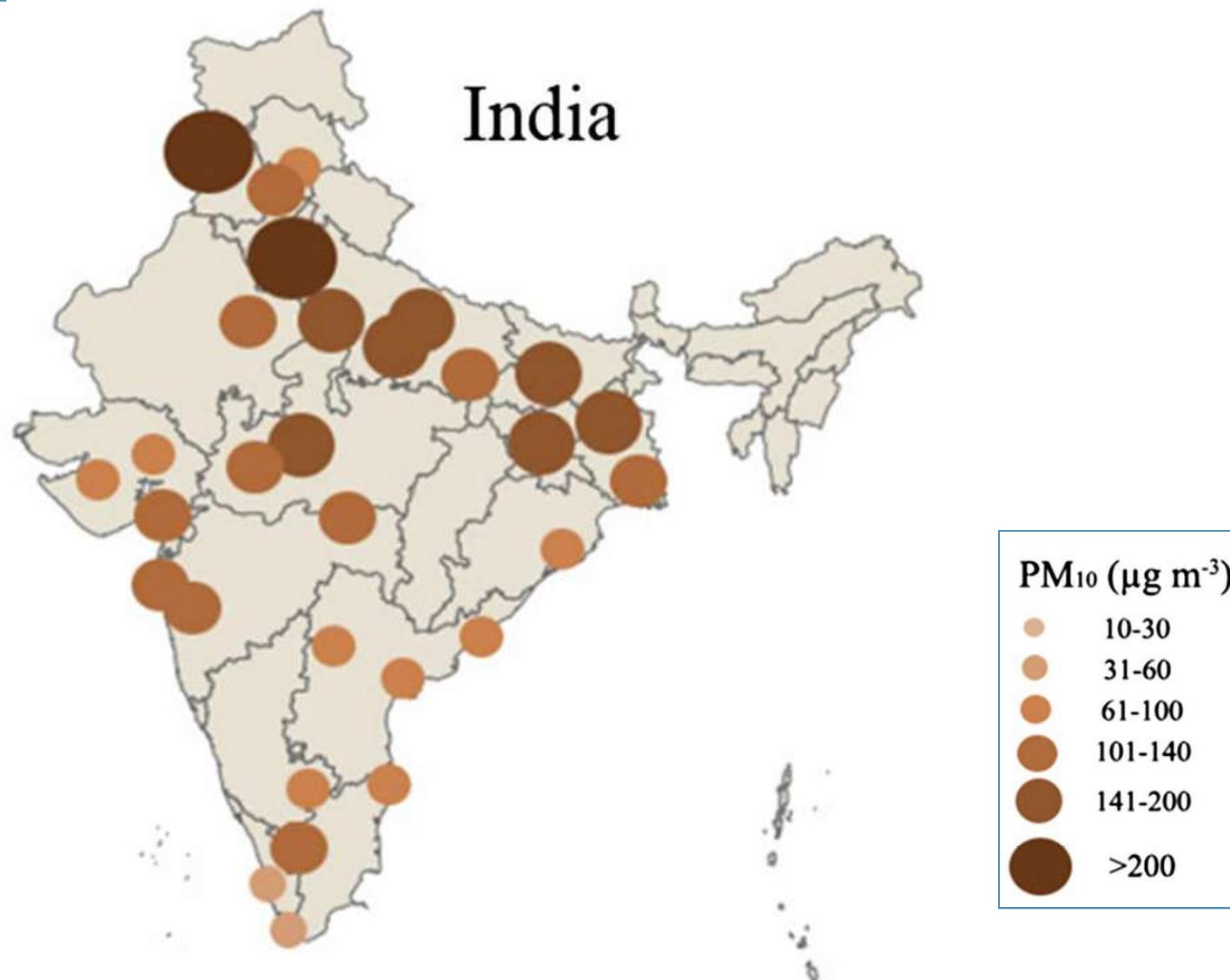
Data Source: World Health Organization
Map Production: Public Health Information and Geographic Information Systems (GIS)
World Health Organization



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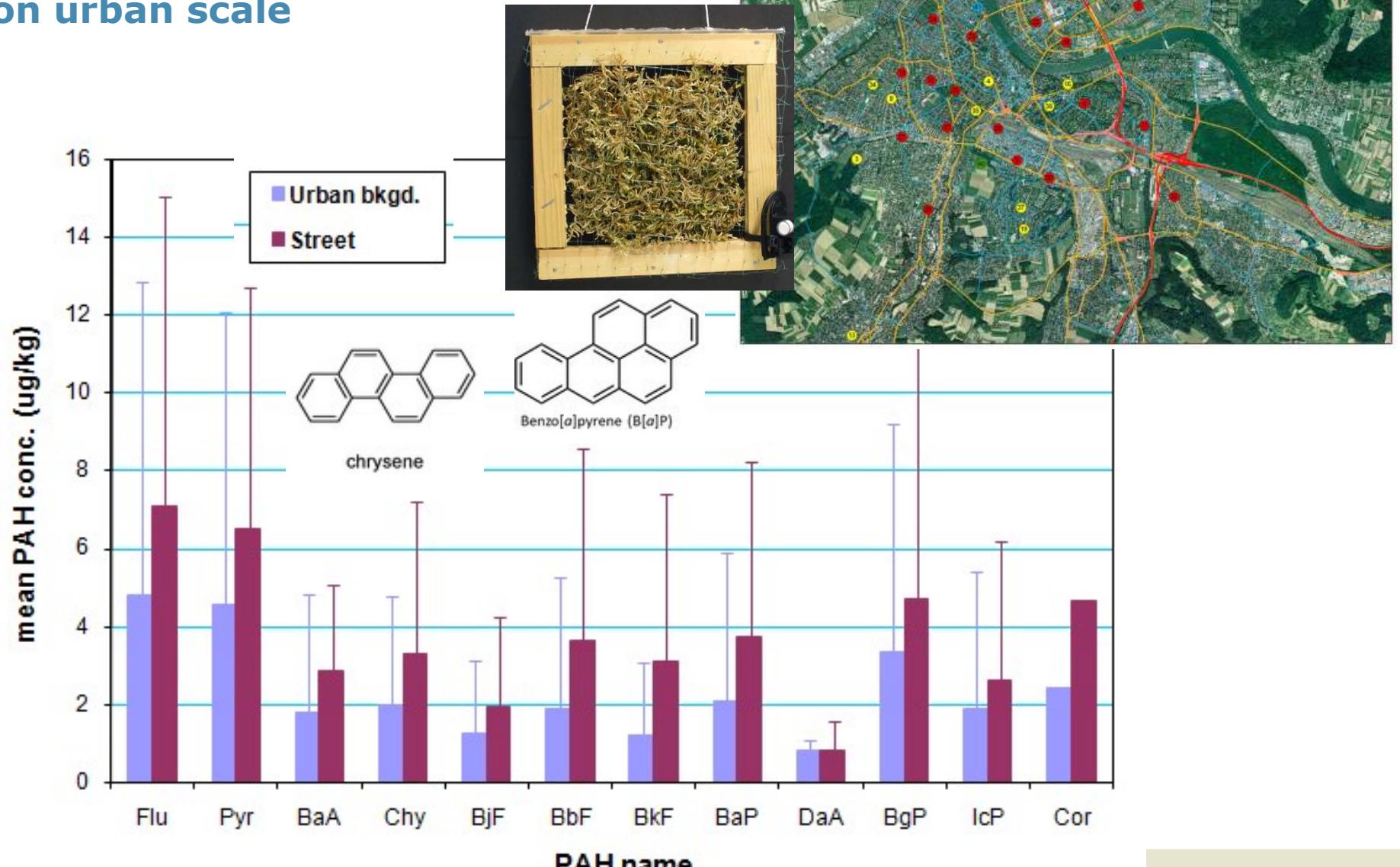
Outdoor PM₁₀ distribution across India

Spatial distribution on National scale



Spatial distribution: PAHs in Urban Basel

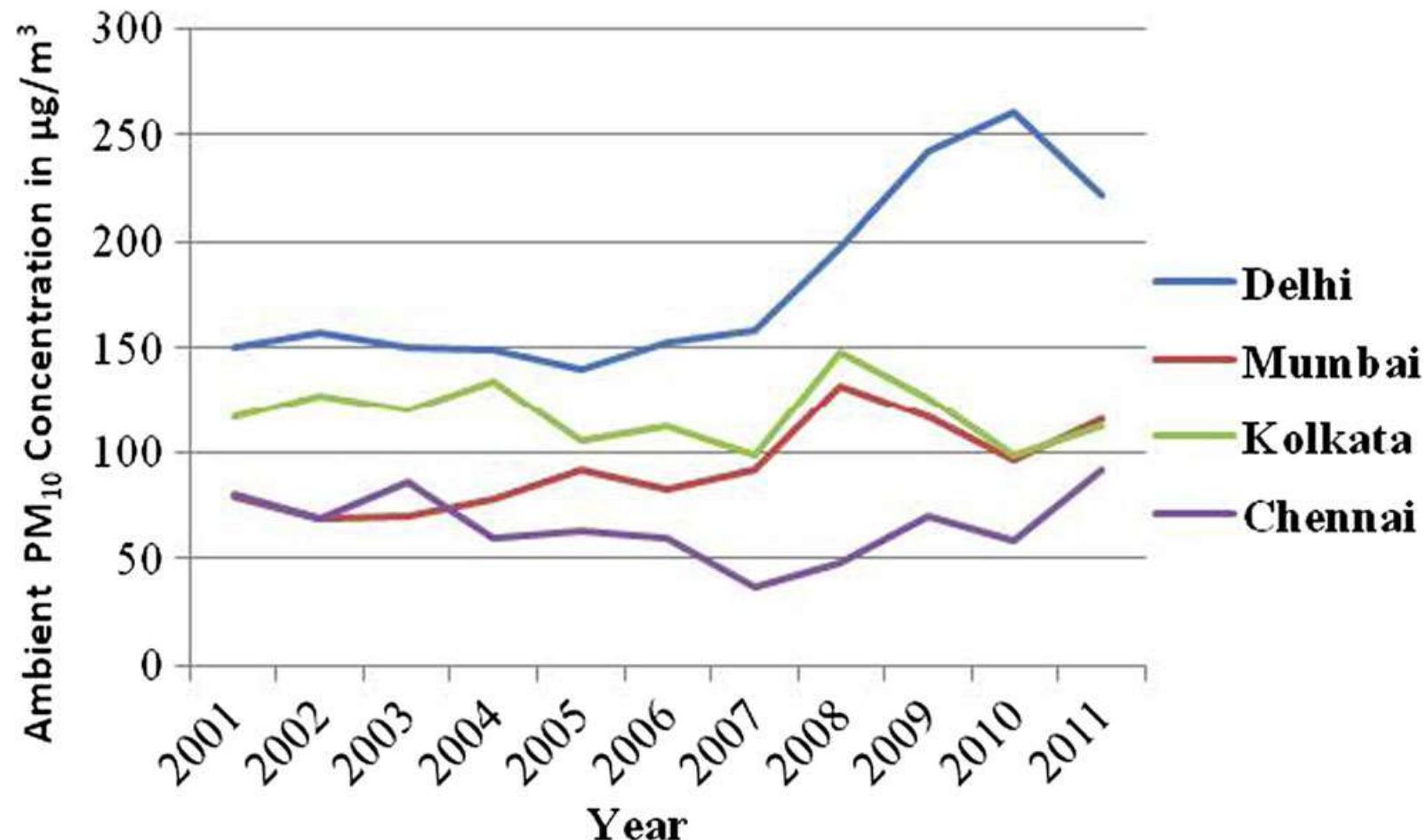
Spatial distribution on urban scale



(Phuleria et al., 2013)

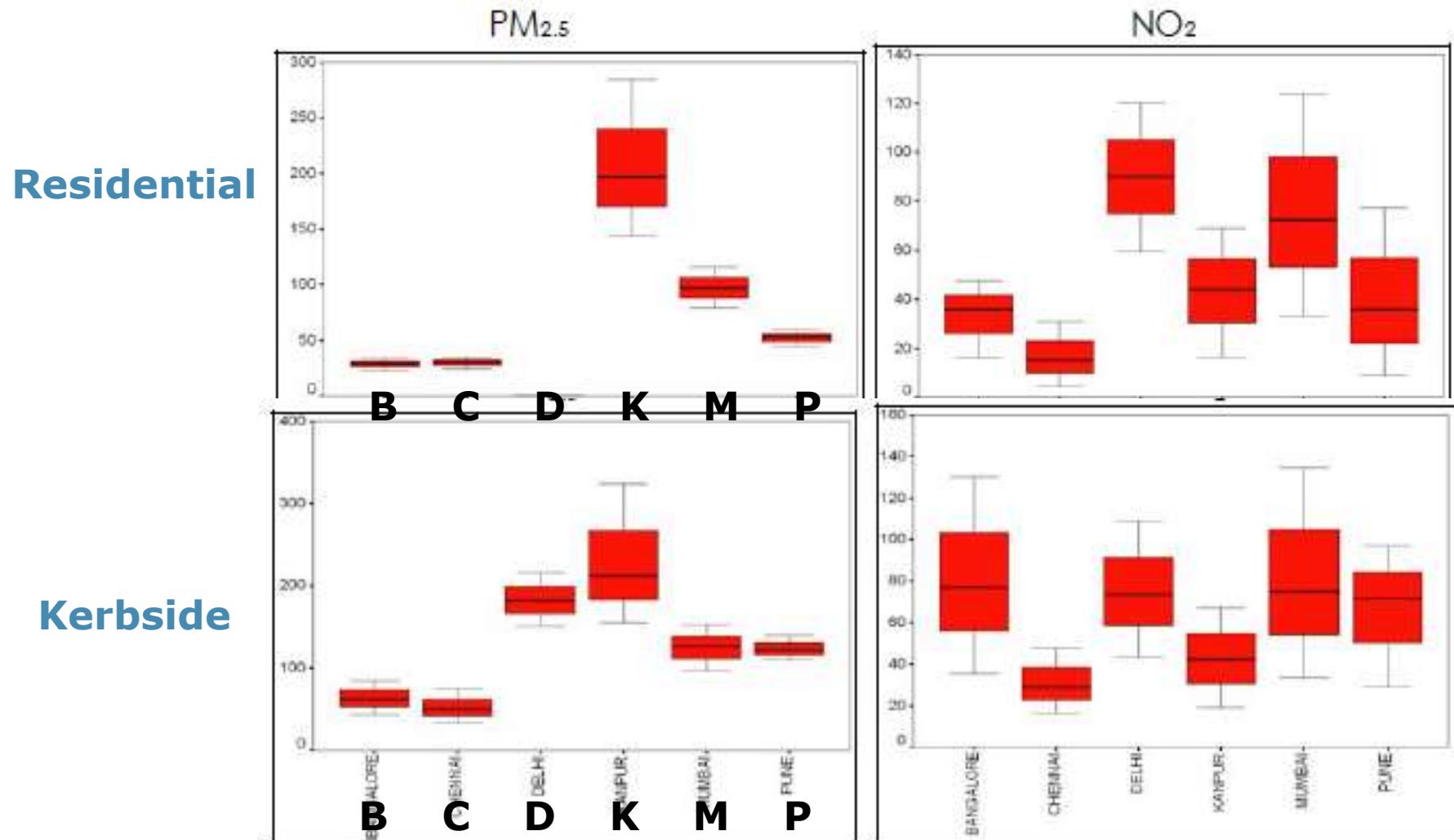
Spatio-temporal variation: PM_{10} in major Indian cities (Six-cities study)

Spatial distribution on national scale;
Temporal distribution annual



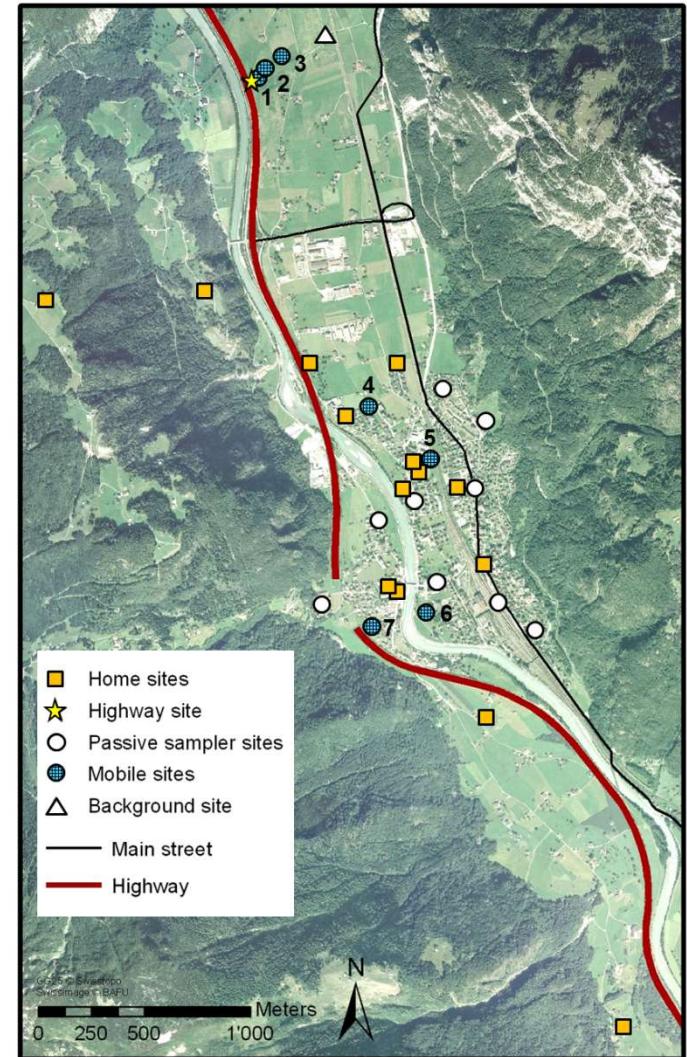
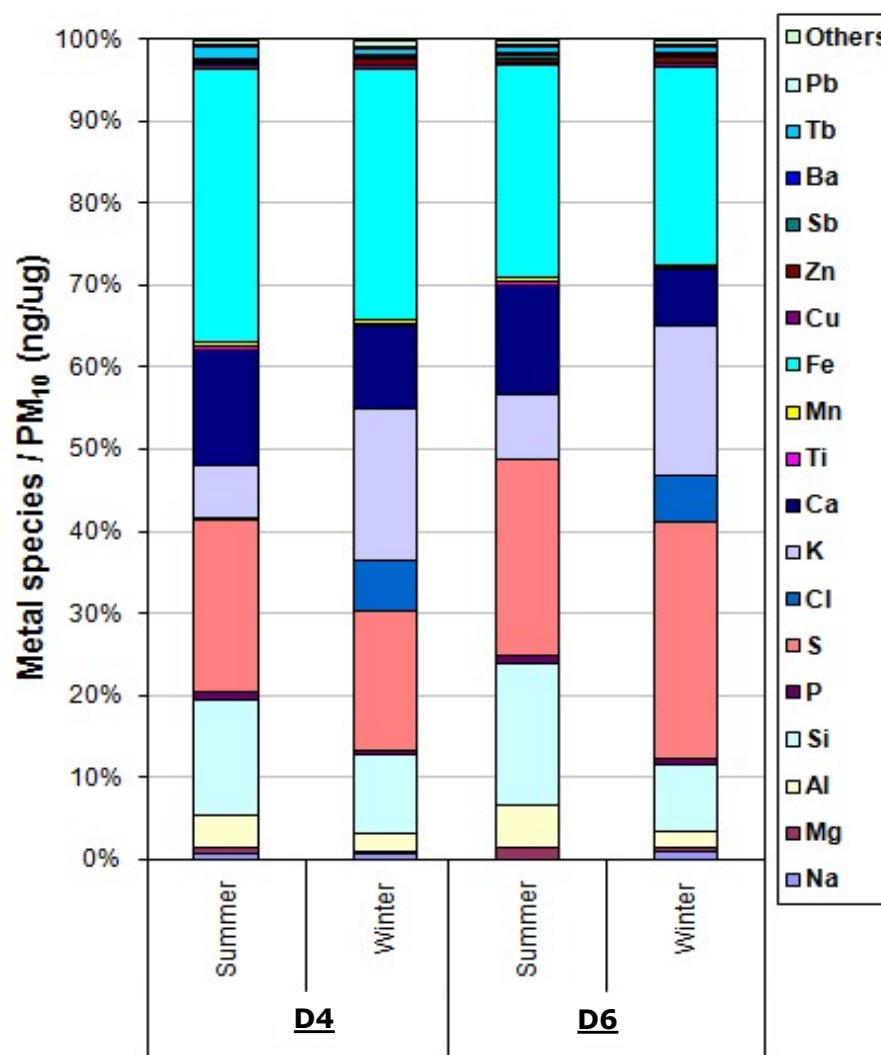
Spatio-temporal variation: $\text{PM}_{2.5}$ & NO_2 in Indian cities (Six-cities study)

Spatial distribution between cities and site types;
Temporal distribution annual



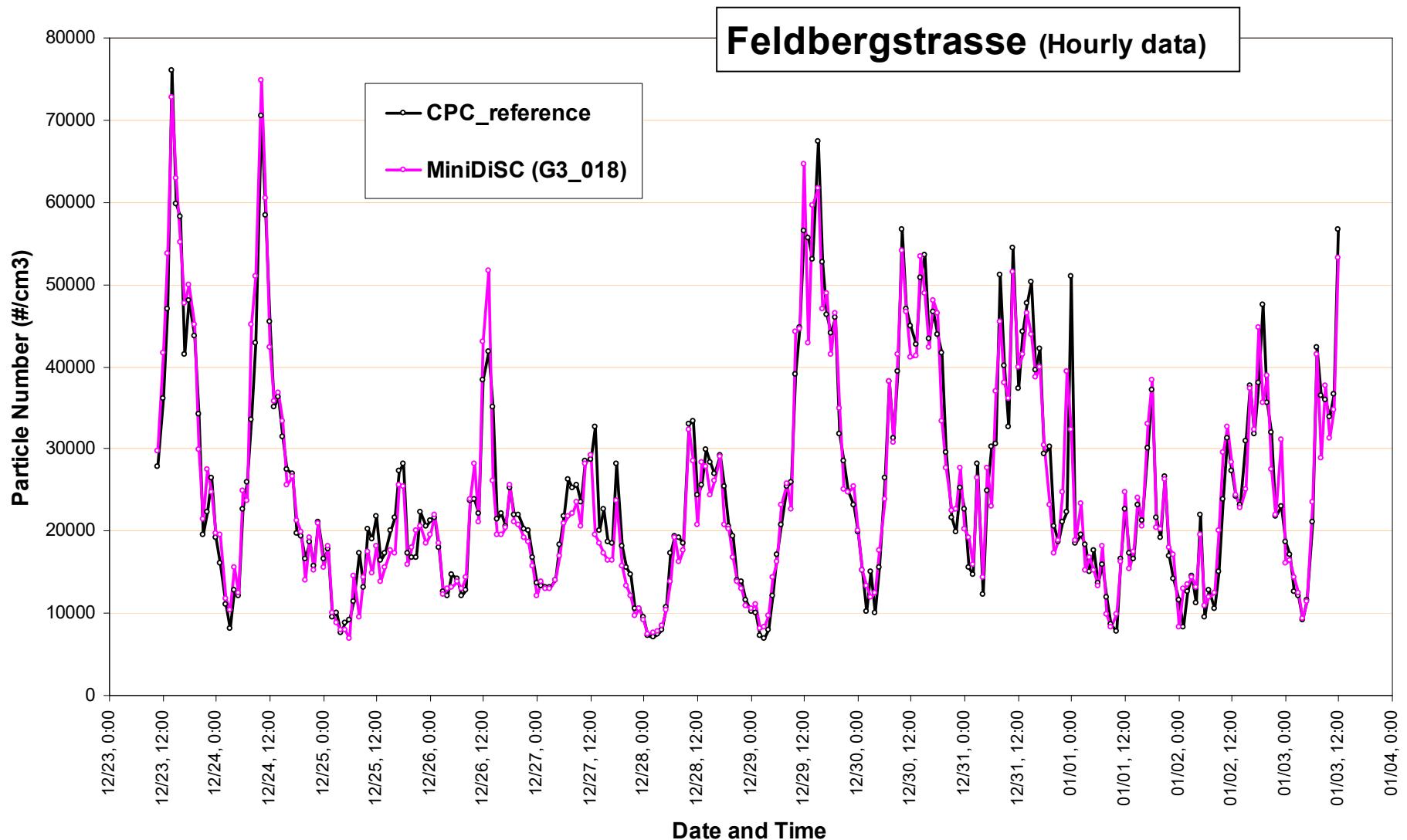
Spatio-seasonal distribution: Trace metals in Erstfeld 2008-09

Spatial distribution on town/village scale;
Temporal distribution seasonal



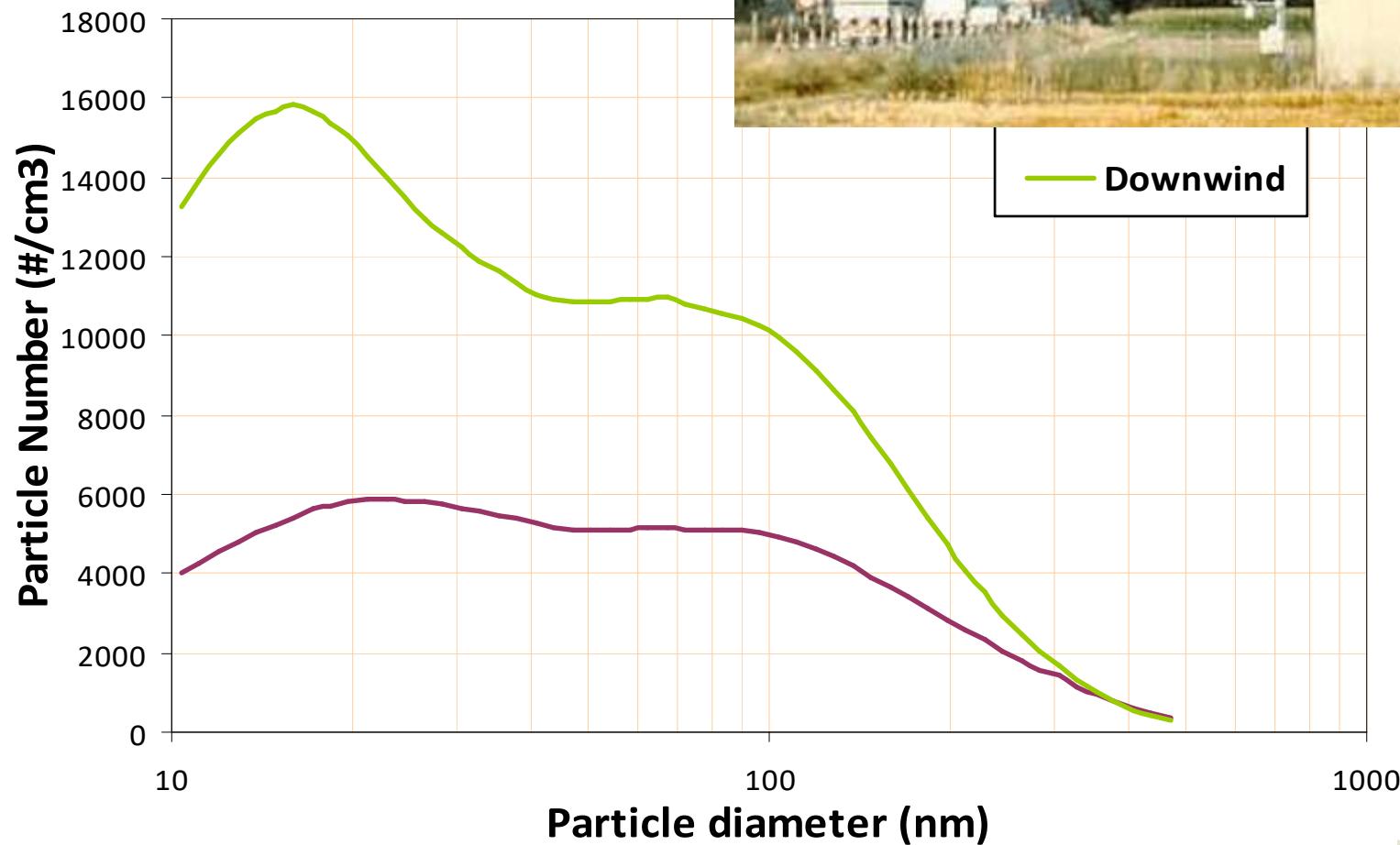
Temporal distribution: Ultrafine Particle in Basel

Temporal distribution hourly



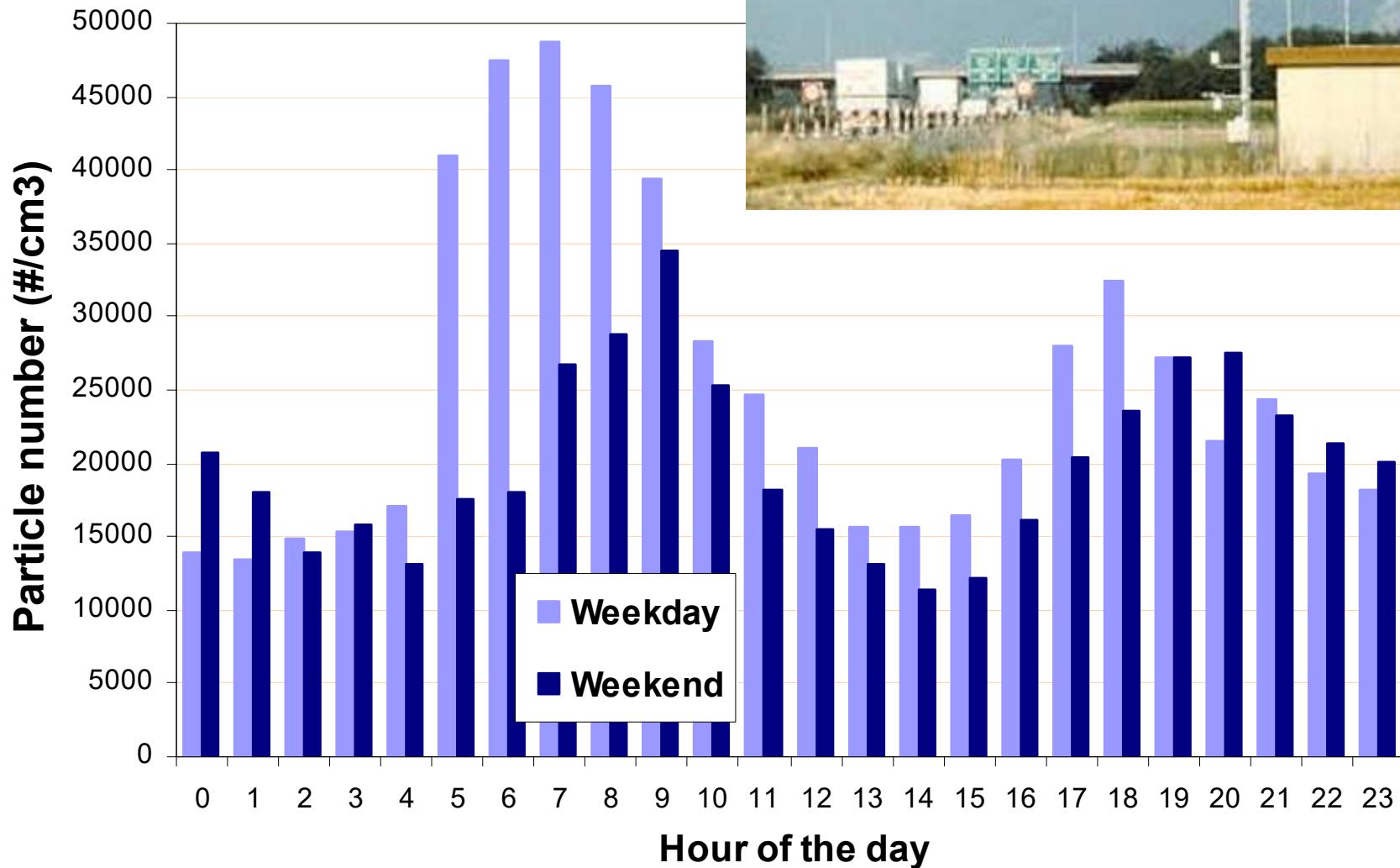
Spatial distribution: Particle size distribution in Haerkingen

Spatial distribution
on urban scale



Diurnal variation: Ultrafine particles in Harkingen

Temporal distribution diurnal



Outdoor, Indoor & Personal NO₂ levels

Spatial distribution on national scale;
Temporal distribution seasonal

