



AIR QUALITY MODELLING TO SUPPORT INITIATIVES ON CLEAN AIR IN CITIES

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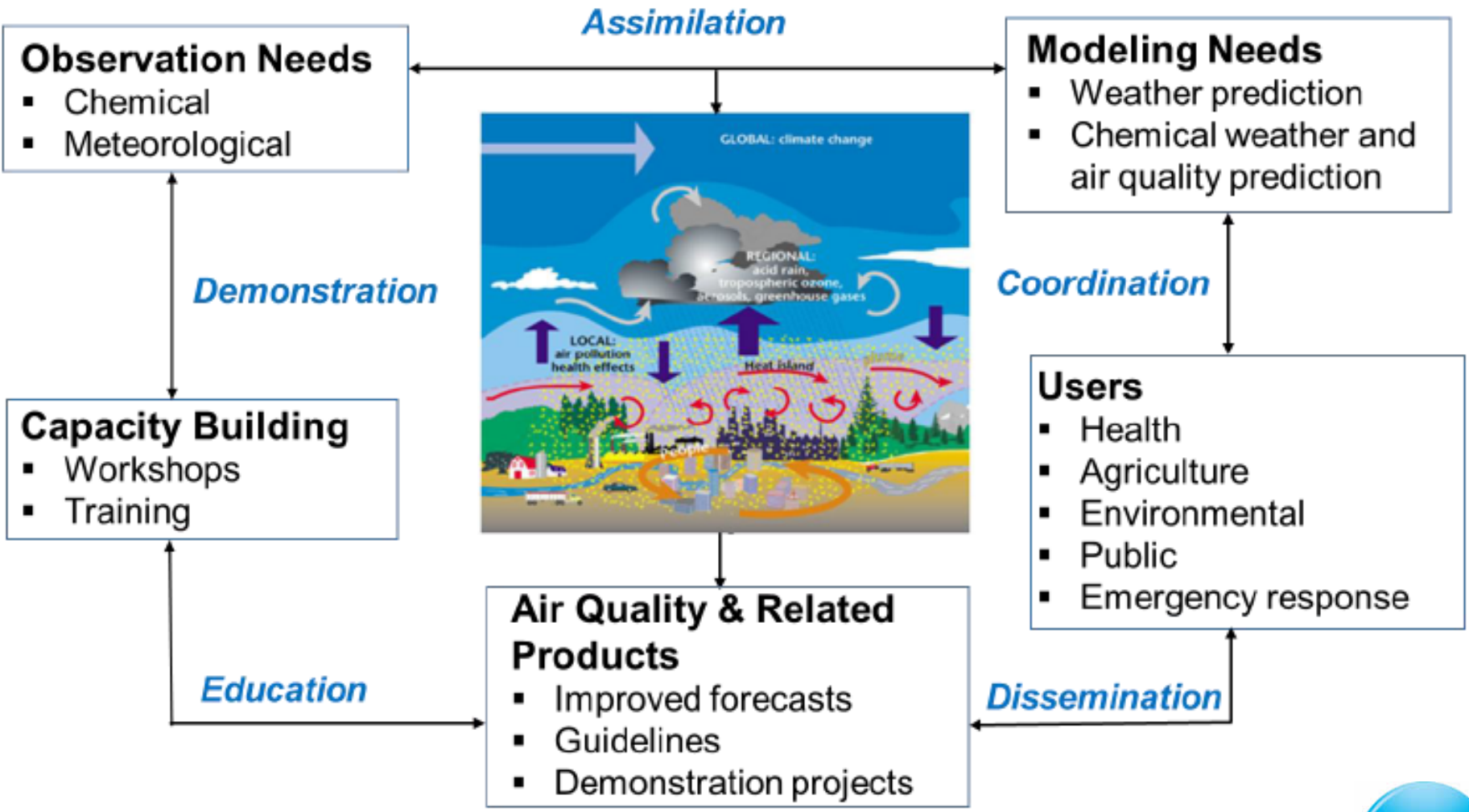
Air Quality related Hazards and Risks affecting Urban Areas

- Urbanization and sustainability
- Poor air quality
- Diverse sources – e.g. traffic, industry
- Wild fires, sand and dust storms
- Heat/cold and human thermal stress
- Extreme weather and climate change
- Climate change - 70% of GHG emission are urban
- Energy consumption
- Local, national, regional governance
- Public health impacts





WMO/GURME Framework for Supporting Integrated Urban Services





Challenges facing global cities

GURME Partner projects

- **Shanghai**
 - Multiple hazards, PM, photochemical
- **Mexico city**
 - Photochemical ozone
- **Singapore**
 - local/LRT
- **Delhi**
 - Long range transport
 - Local sources
- **Chilean cities**
 - Complex terrain/episodes
- **Paris** (urban meteorology)
 - Local/regional, multi-pollutant impacts
 - Urban met., climate, UHI, heat stress
- **Moscow** (new initiative)
 - new air quality forecasting

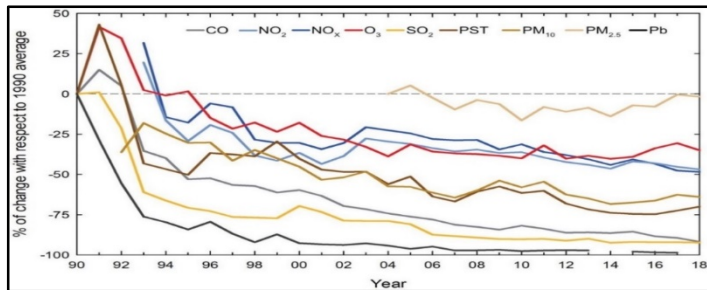
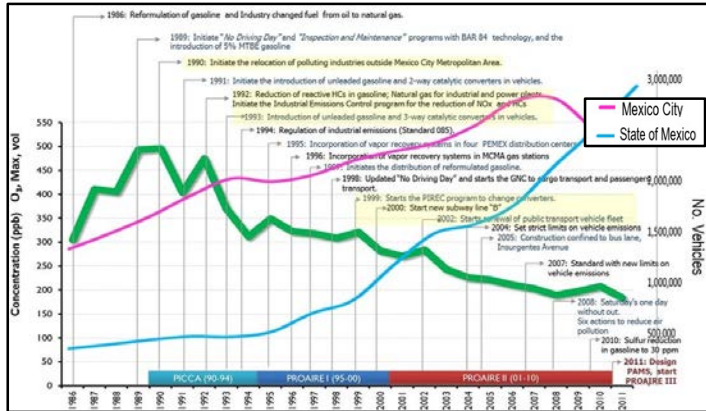
Discussed in this presentation
Plus European cities

Mexico City – progress and challenges

Late 1980s - early 1990s:

All criteria pollutants frequently exceeded AQ Standards; O₃ peaked above 300 ppb many days

• Reduction in all criteria pollutants



% Reduction from 1990 based on annual average

(Source: Molina et al., Atmosphere, 2019)

AQ Management Programs – significant measures implemented

- Extensive ambient **AQ monitoring stations**
- **Emissions inventory** (update every 2 yrs)
- Air Quality **Standards** (PM10, PM2.5, NO₂, SO₂, CO, Pb, O₃)
- **Transportation**
 - removal of lead from gasoline and its reformulation
 - mandatory use of catalytic converters
 - reduce sulfur content in diesel fuel
 - reinforce vehicle inspection and “no driving day” rule
 - implement air pollution contingency program
- **Industrial and residential sectors**
 - substitute fuel oil in industry and power plants with natural gas
 - reformulate LPG for cooking and water heating
 - promote energy efficient buildings and solar water heating
- Collaborate with **national and international researchers**
- Develop **Air Quality Forecasting System**
- Engage **Health sector** in evaluation of air pollution impacts
- Enhance **communication** with public and stakeholders

Ongoing Challenges:

Reduction in O₃ and PM slow

Complex interactions between **meteorology, emissions and atmospheric chemistry**

Regional Coordination Challenge: Central Mexico Megalopolis

Expansion of the Mexico City Metropolitan Area (MCMA) has produced the “Megalopolis” - Mexico City and the contiguous municipalities of surrounding states (Mexico, Puebla, Tlaxcala, Morelos, Hidalgo, Queretaro)

- Population: 31 M (~25% of Mexico national population)
- GDP: ~33% of the National

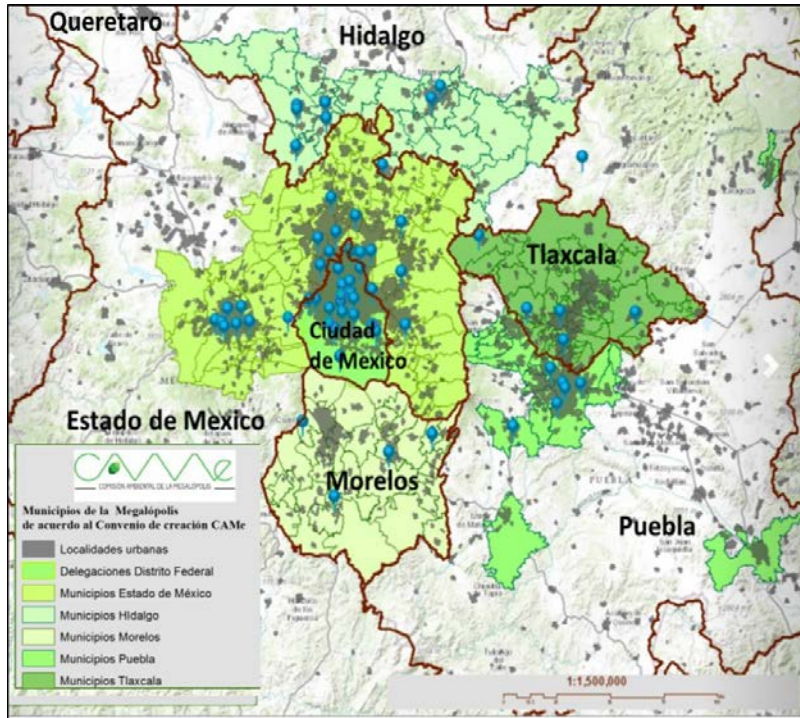
❑ Limited environmental policy coordination with different administrative and legislative jurisdictions

- 2013: Megalopolis Environmental Commission (CAME) was created to coordinate regional policies and programs

❑ Limited air quality monitoring and air pollution studies (except for the MCMA)

❑ Important to strengthen capacity building

- Increase ambient AQ monitoring stations
- Conduct field studies of O₃ precursors and other pollutants
- Evaluate the uncertainties in the emission inventories for estimating the impacts of air pollutants in the region



**Map of the Megalopolis
(blue circles indicate the
ambient air quality monitoring
stations)**

Source:

<https://www.gob.mx/comisionambiental/>

Source: Luisa Molina

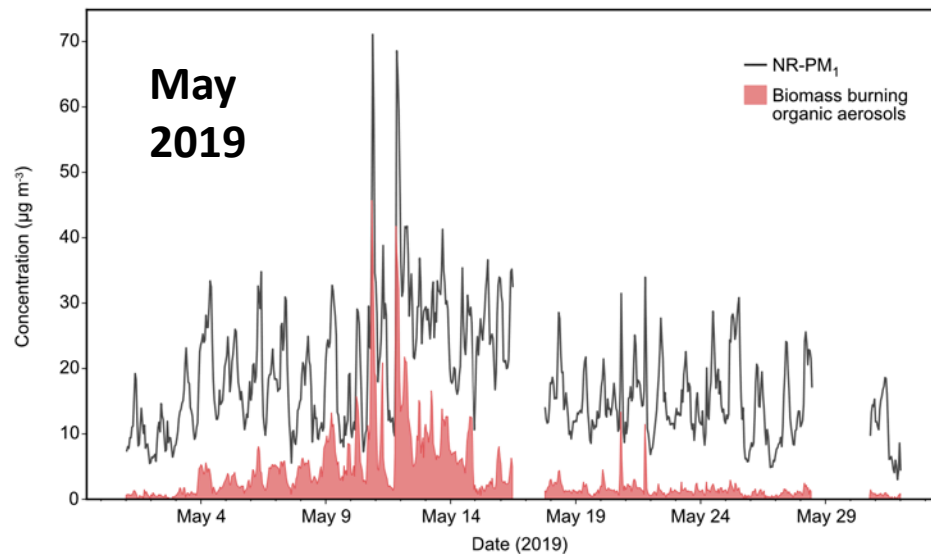
(Molina et. al., Atmosphere, 2019)

Regional biomass burning contribution to PM

Mexico City Metropolitan Area



Contributions of biomass burning organic aerosols to the non-refractory PM₁ during May 2019 event



(Credit: Retama et al., work in progress, 2020)

- May 2019 - a severe air pollution episode caused by regional wildfires;
- During the dry season, the air masses advected from the regional fires generate significant amounts of organic aerosols with different levels of oxidation, VOC's and reactive gases.
- AQ management plans do not take this contribution into account in their strategies.
- **O₃ levels 142 ppb & PM_{2.5} levels of 81.4 $\mu\text{g m}^{-3}$**
- New actions e.g driving restriction to 50% of Mexico City government official vehicles.

Complex processes:

Interplay between natural & anthropogenic activities

Complex topography

Episodic meteorological conditions

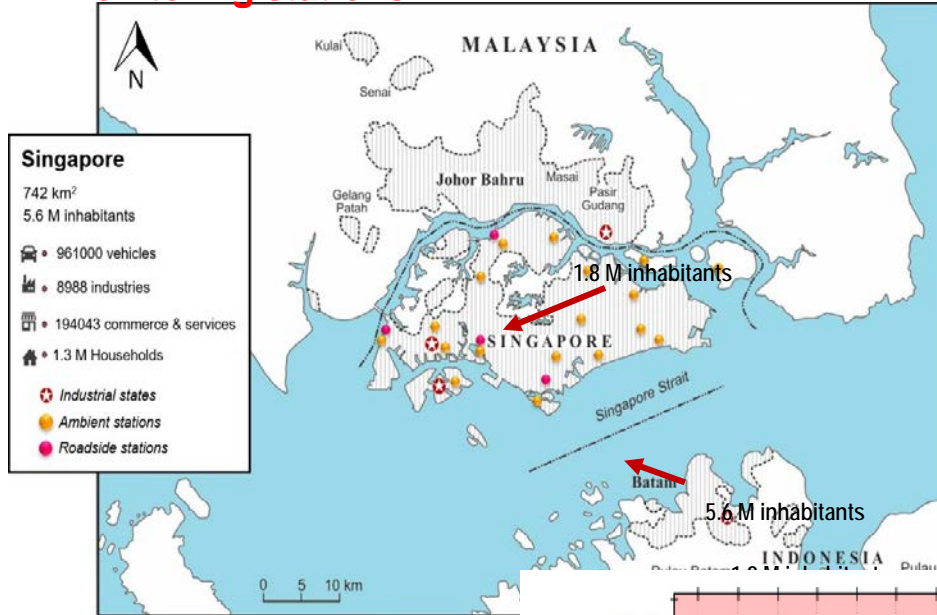
Source: Luisa Molina

Yellow and red dots are locations of ambient and roadside air quality monitoring stations

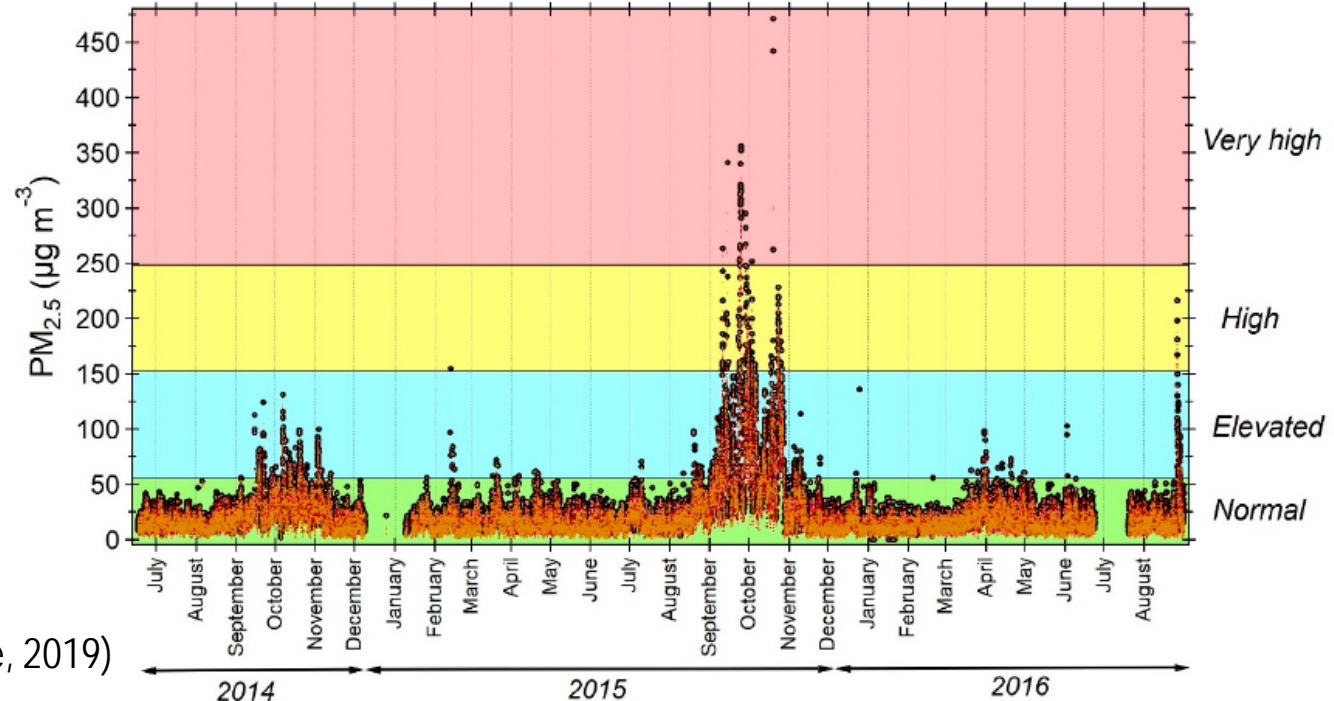
Singapore – mixed local and LRT contributions

➤ Main air pollution challenges:

- **Local emissions** from vehicles and industry.
- **Transboundary air pollution** from the highly industrialized and urbanized neighboring cities of Johor Bahru and Batam.
- **Haze episodes** from neighboring Indonesia's wildfires



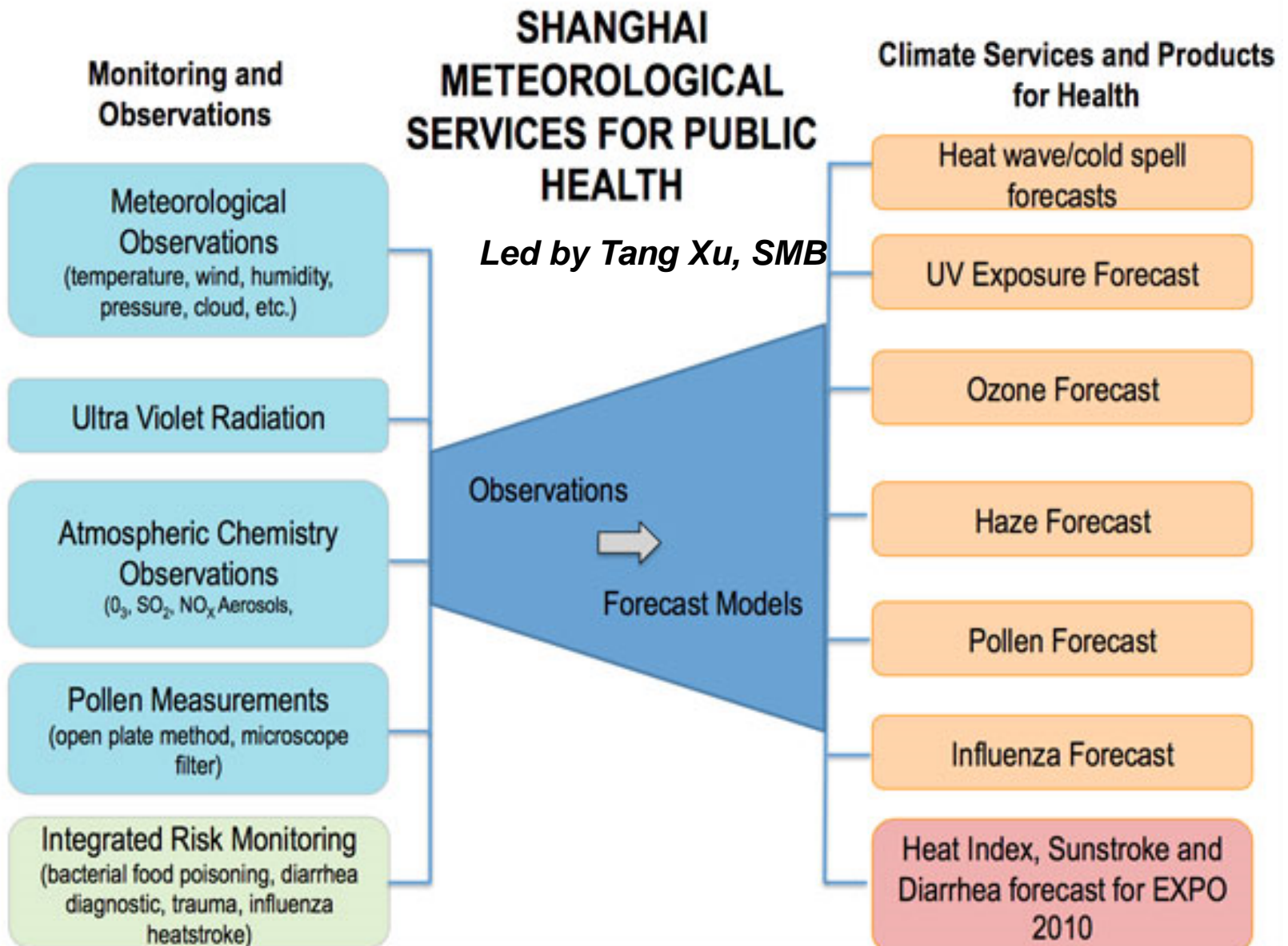
Map of Sijori Growth Triangle (total population = 8.6M) formed by the urban areas (shade area) of Singapore, Johor Bahru in Malaysia to the north and the Indonesia's island of Batam to the south.



(Source: Molina et al., Atmosphere, 2019)

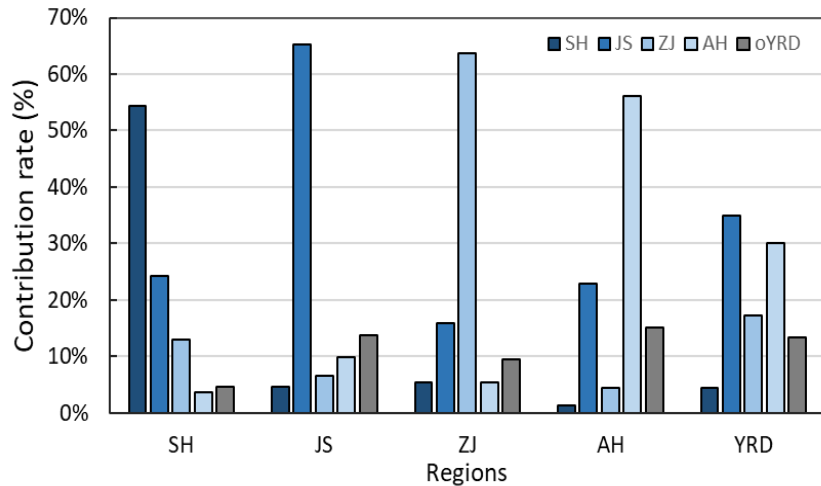


GURME Project part of Shanghai Multi-Hazard Early Warning System (MHEWS) (by SMB/CMA)

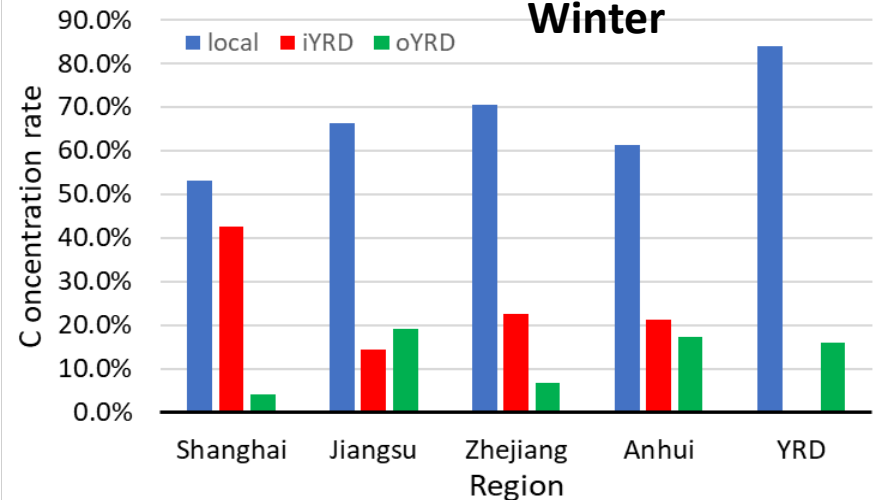


WRF-Chem analysis: PM_{2.5} over Yangtze River Delta (YRD) region (Shanghai, Jiangsu, Anhui and Zhejiang)

- Local emissions contribute 55-65% for PM_{2.5} concentrations over YRD provincial regions, and 85% for YRD in 2019
- Comparable transport contribution rate annually and in winter
- Inner/mutual transport in YRD (iYRD) contribution varies ~20-40%
- Relatively higher cross-regional (oYRD) transport in winter for north part (JS and AH)



Source apportionment by WRF- Chem modeling in 2019

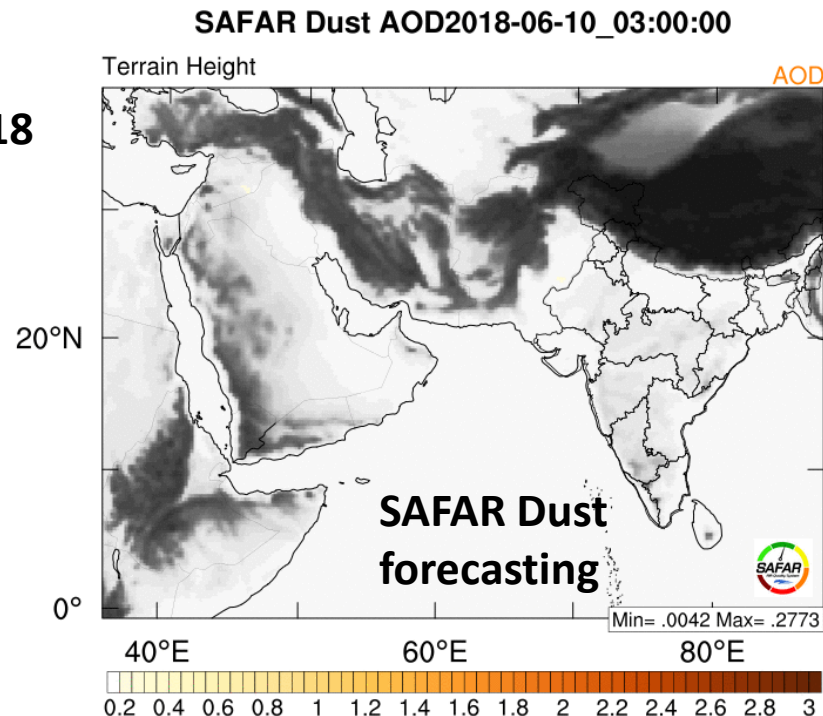
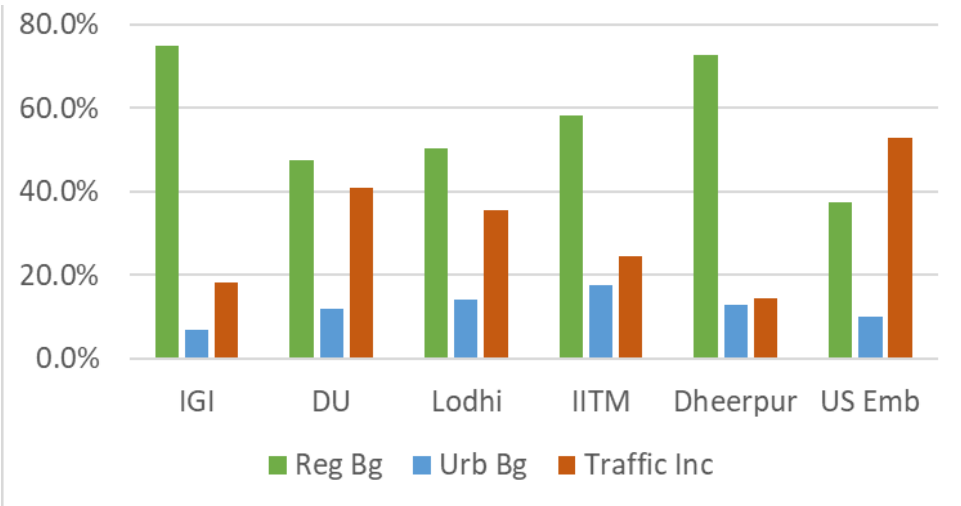


Source apportionment Nov. 2018- Feb. 2019

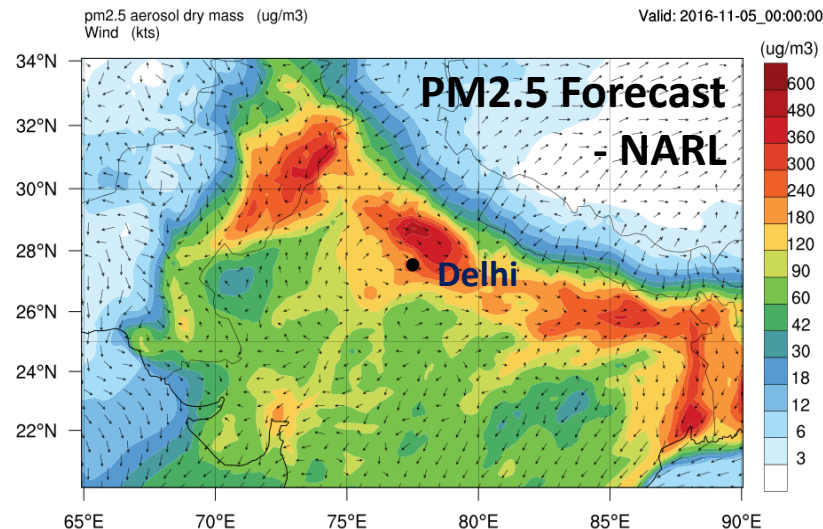
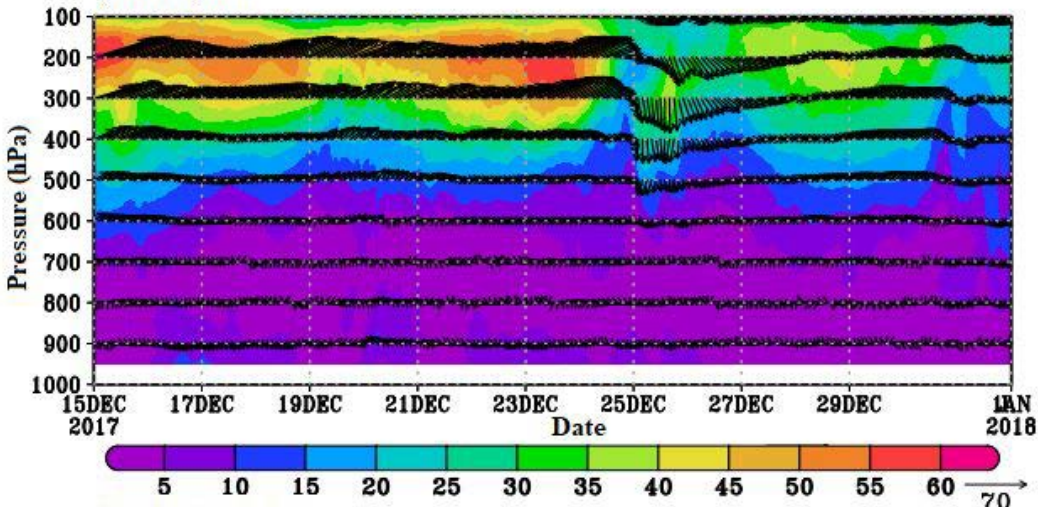
Local emissions contribute nearly 2/3 of PM_{2.5} and LRT accounts for 1/3

PROMOTE: Analysis and forecasting for Delhi, India

OSCAR-WRF-Chem PM2.5 Analysis for Delhi Local, urban, regional contributions – Winter 2018



a) Wind speed WRF Model – vertical analysis



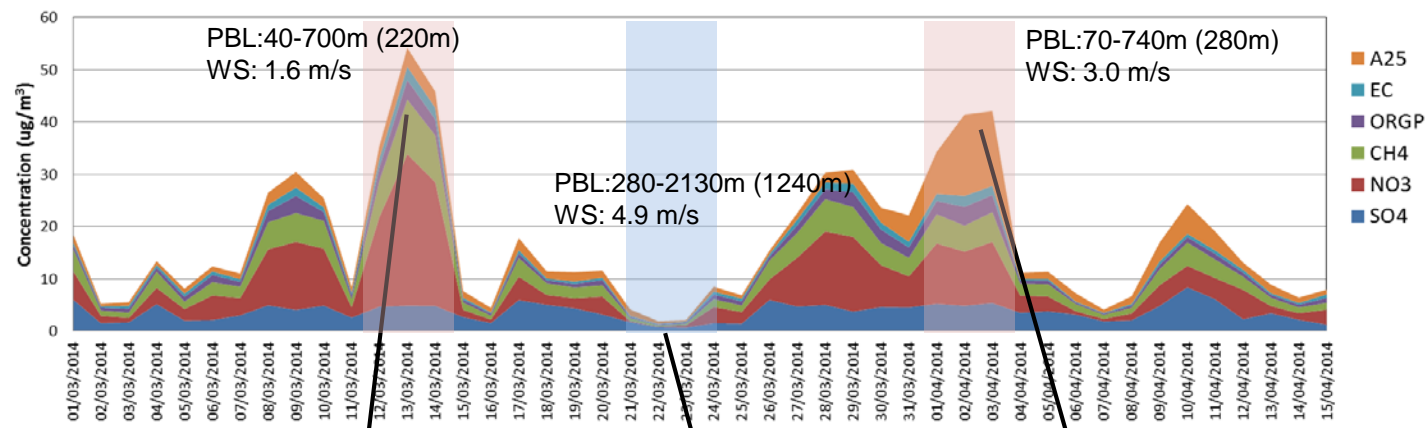


Understanding air pollution episodes

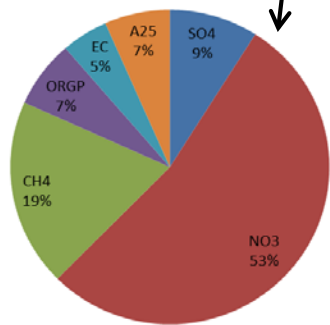
Modelling Analysis of PM2.5 air pollution over S. England

Regional PM2.5 episode over the South England (March – April 2014)

Composition of PM2.5 at Rural Site (HAR)

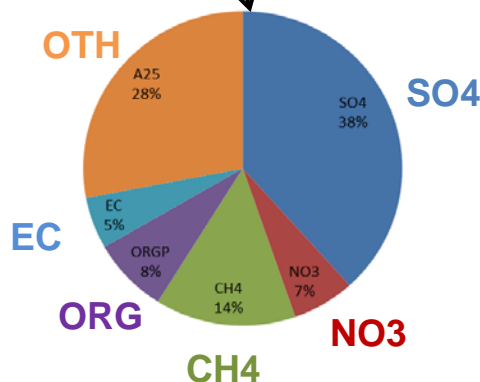


13 March 2014

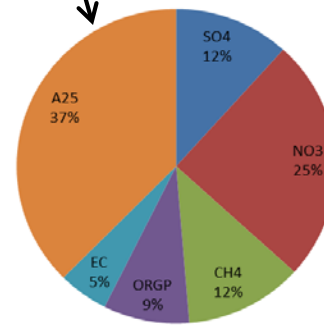


Nitrate dominated

22 March 2014



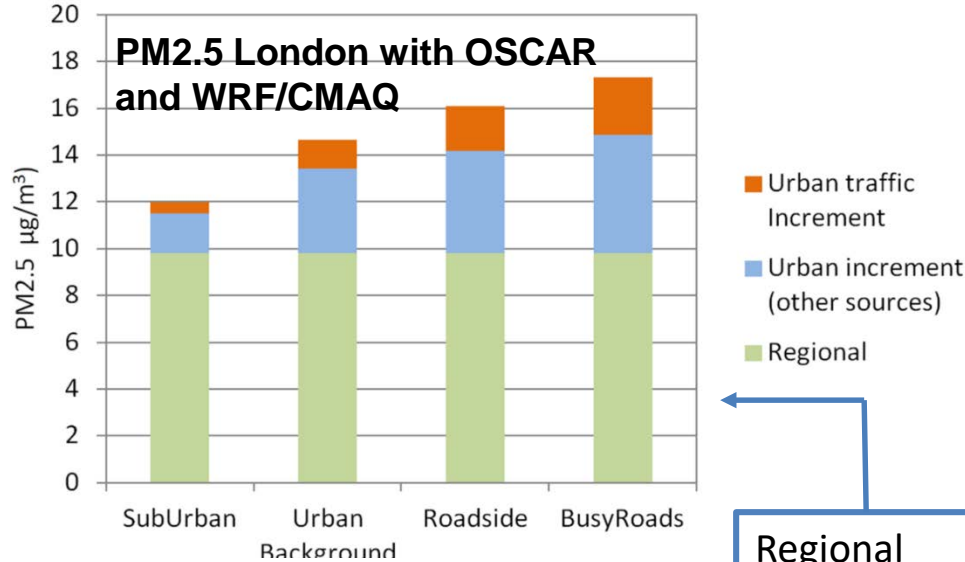
2 April 2014



Mixed - Nitrate and Dust

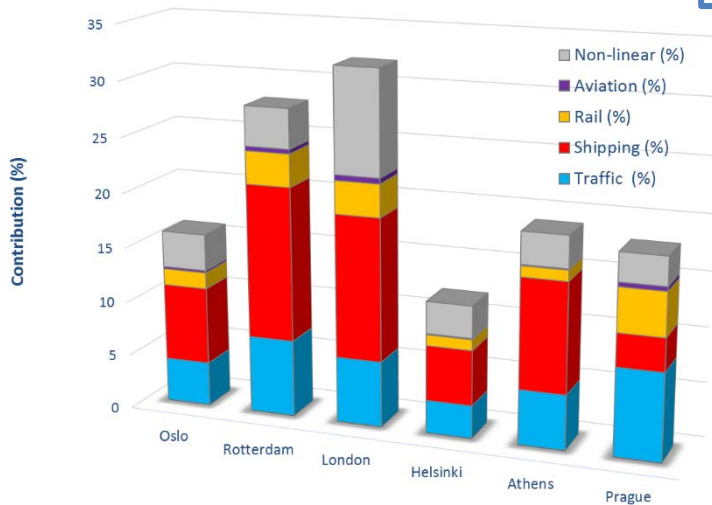
Local and regional contributions to Particulate Matter

Transport related Air Pollution and Health impacts - Integrated Methodologies for Assessing Particulate Matter



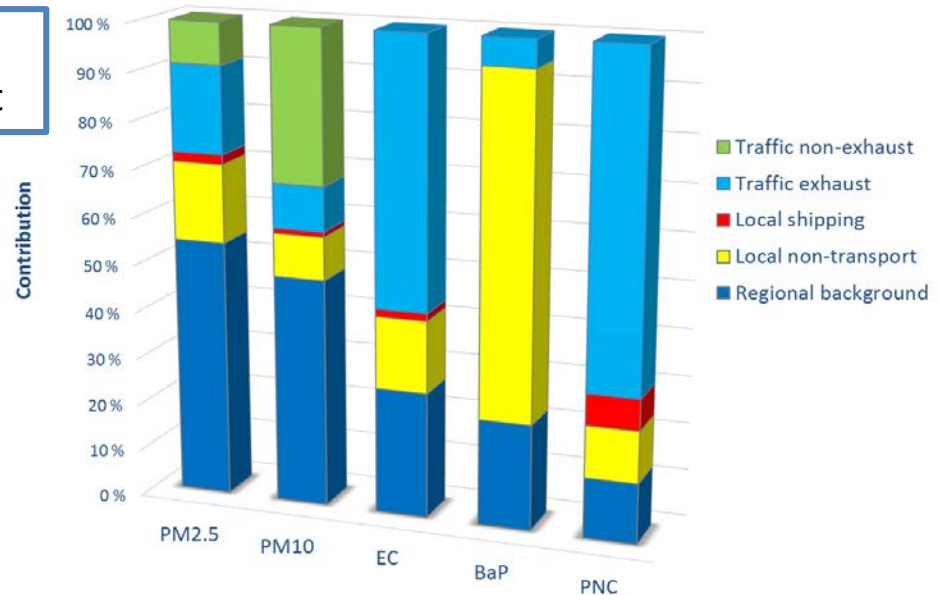
Pollutant	Source orientated response
PM10	Coarse e.g. road dust
PM2.5	Regional dominant, exhaust
EC	Combustion, exhaust
BaP	Wood burning
PN	Combustion, exhaust

Regional background source contribution to PM2.5 at target cities

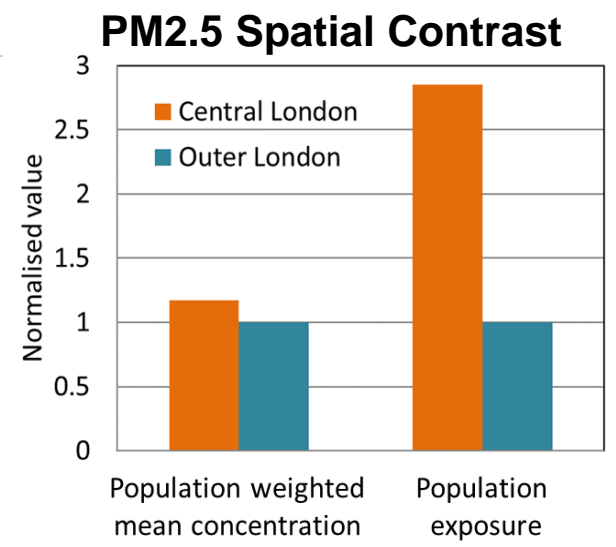
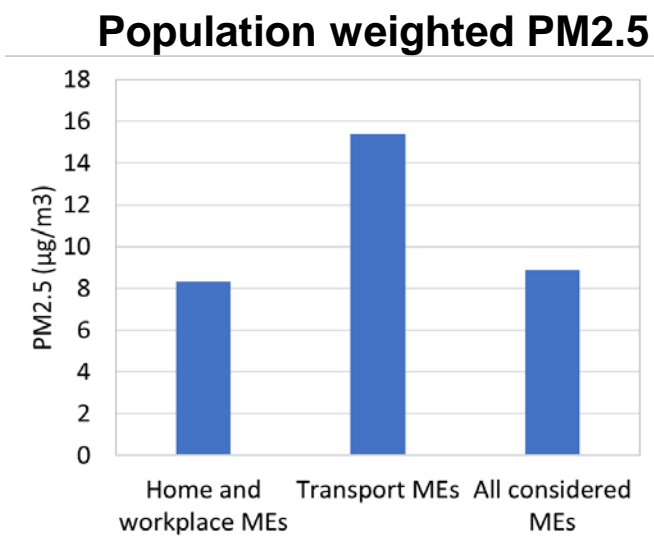
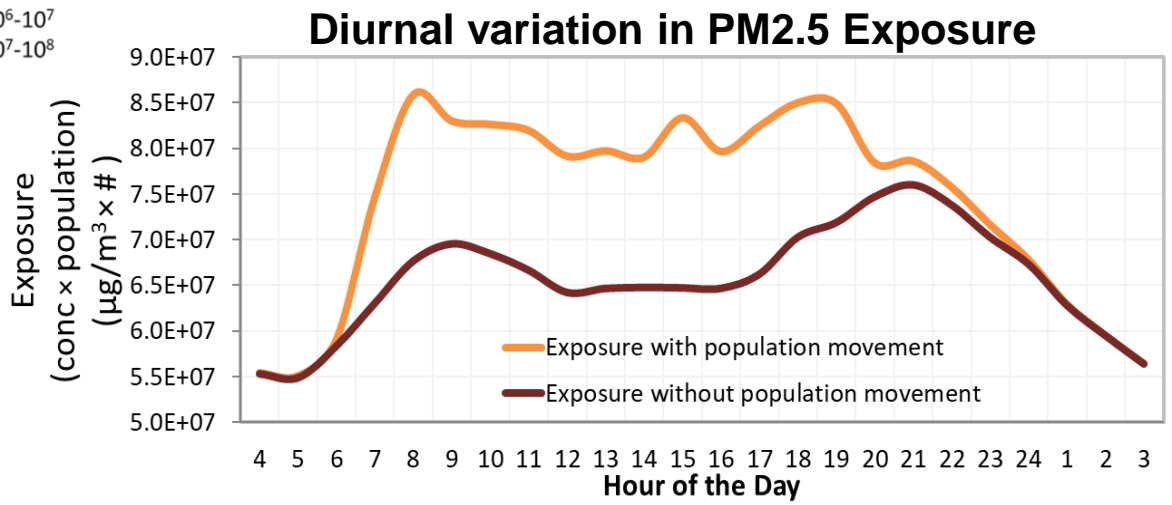
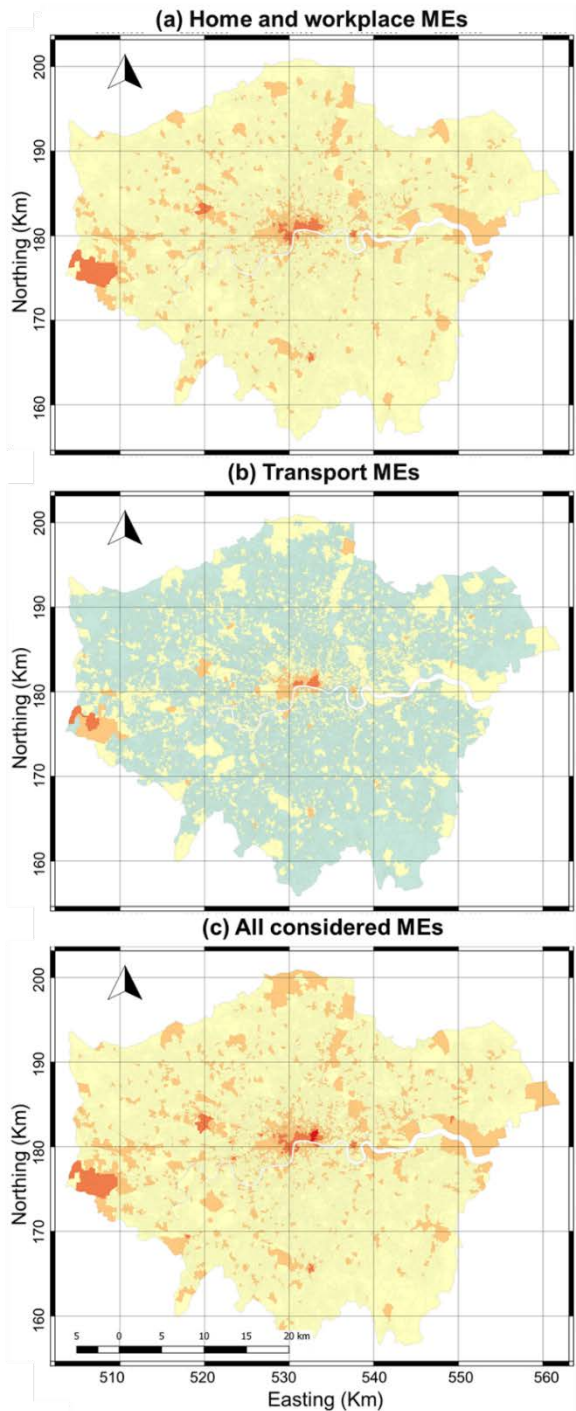


Regional component

Source contribution to PM exposure in Oslo



Spatial and temporal variation in exposure to PM2.5 over London





Towards improving air quality in cities

Concluding remarks

Air quality prediction and forecasting – process analysis

- Multiscale approach linking local, urban and regional scales
- Move towards exposure and health impact based analysis for cities
- Testing efficacy of mitigation strategies and impact of technological solution

Improve emission inventories

- Inadequate or have not been evaluated in many regions
- Source apportionment, inverse modelling

Integrated observations – extend spatial and temporal coverage

- Extend air quality monitoring
- Extend measurement of chemical species e.g. for PM
- Combination of ground based and satellite data
- Consider supersites for comprehensive measurements

Strengthen coordination, and cooperation

- Develop data quality protocols (QA/QC)
- Greater cooperation between local, regional and national governments and agencies

Build capacity and training

- Capacity building to respond to support policy