# AIR QUALITY CHALLENGES FACING GLOBAL CITIES: OBSERVATIONAL AND MODELLING ANALYSIS

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**2nd Expert Panel on Clean Air in Cities (EPCAC)**
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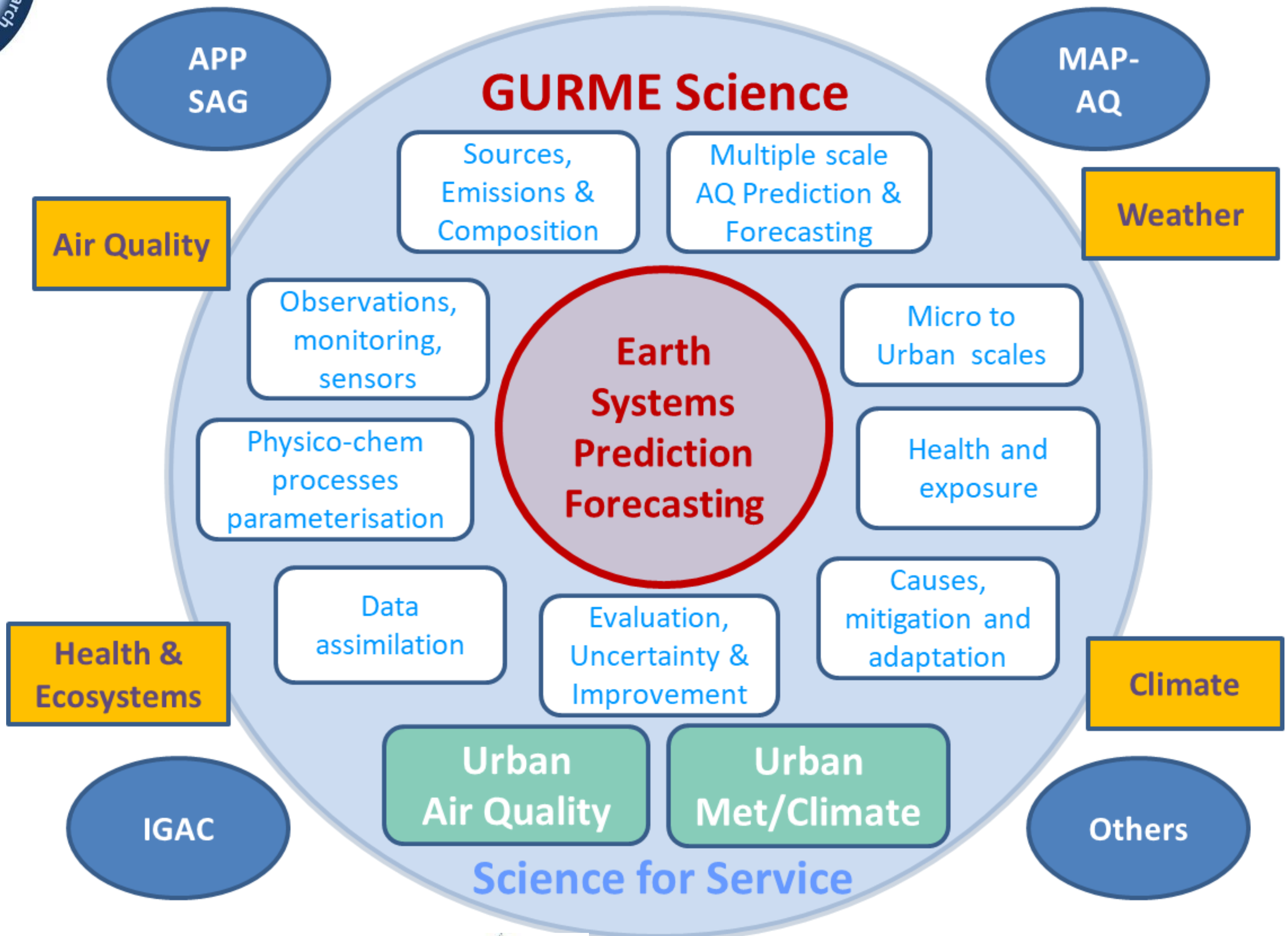
- Ministry of Earth Sciences (MOES), India

# Format of presentation

- WMO/GAW Urban Science – GURME
- Challenges facing Global Cities
- WMO/GAW study on Air Quality during COVID Lockdown
- Conclusions
- Remarks on an EPCAC Air Quality modelling study

# WMO/GAW URBAN Research in Meteorology and Environment (GURME)

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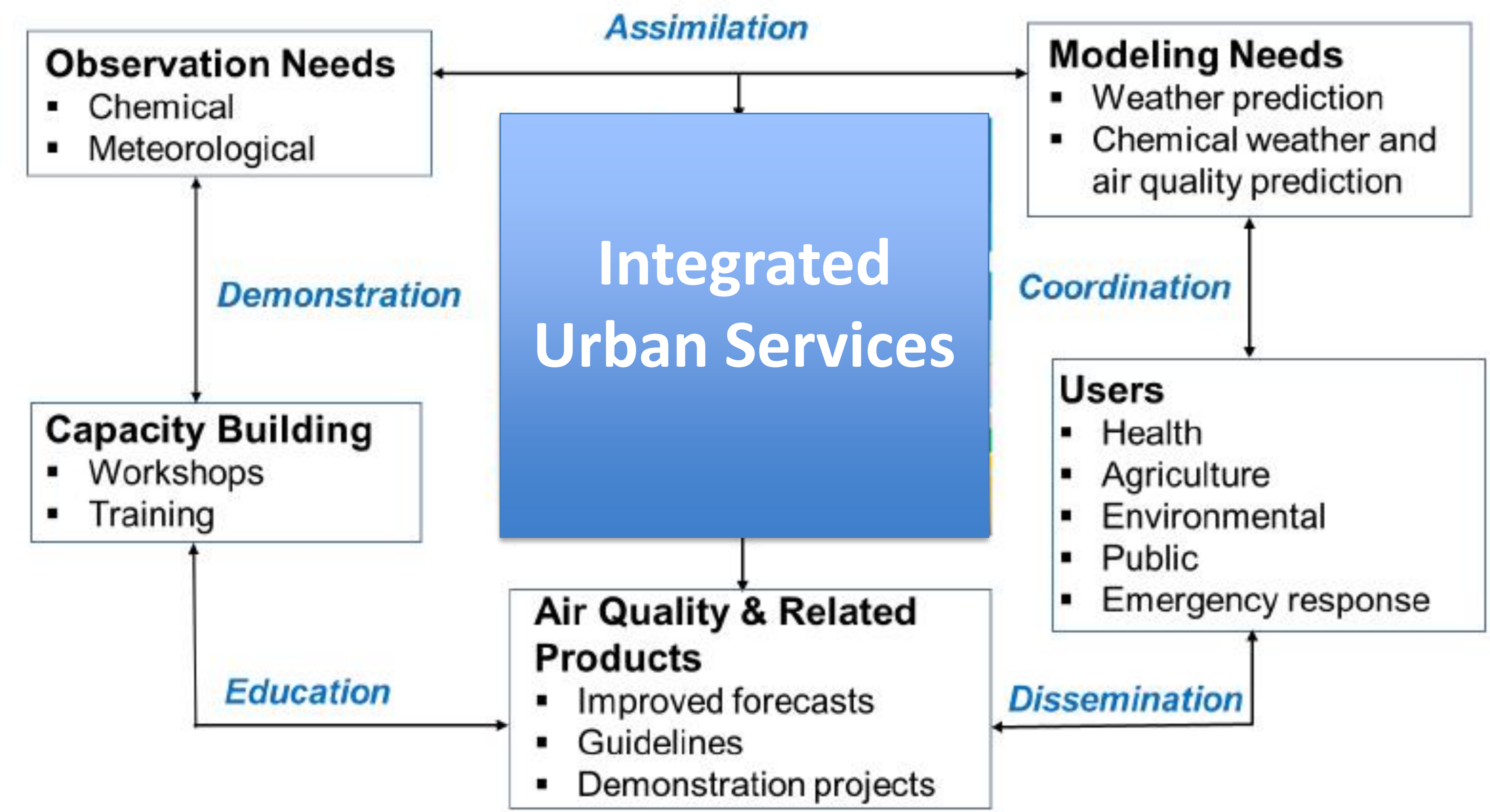
WMO

GAW

GURME

# GAW Urban Research in Meteorology and Environment Project (GURME): Integrated Urban Services




WMO OMM

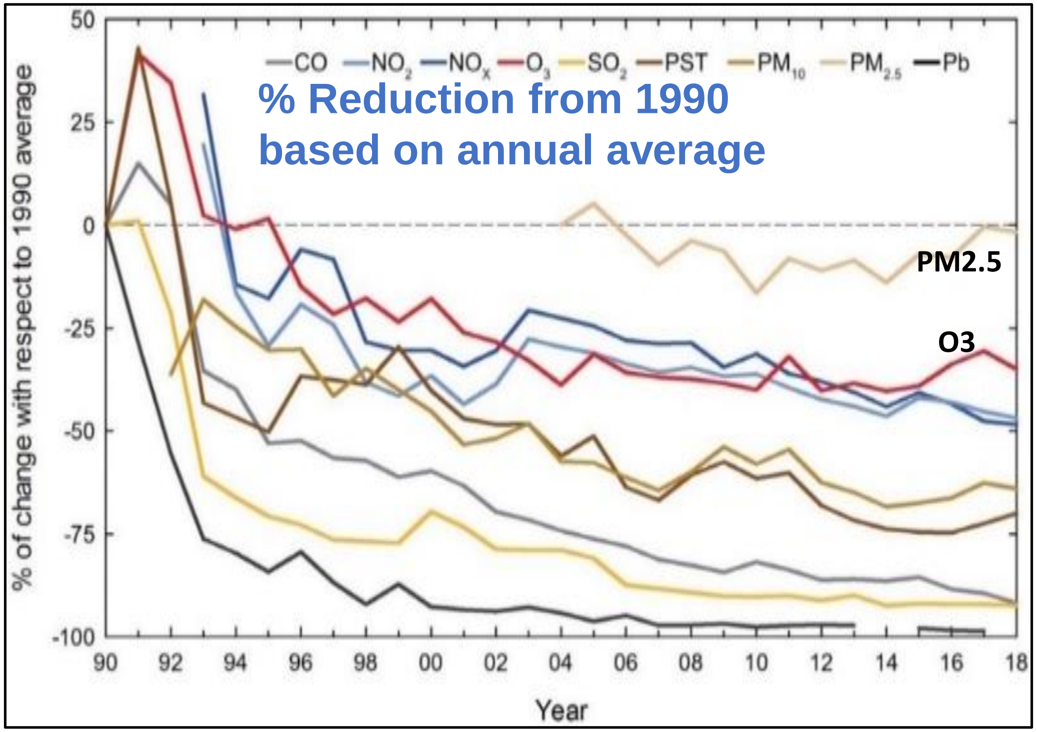
https://public.wmo.int/en/our-mandate/focus-areas/urban-development-megacities/wmo-and-new-urban-agenda
http://www.wmo.int/pages/prog/arep/gaw/urban.html
http://mce2.org/wmogurme/

# GURME focus:
# Challenges facing global cities

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

**Discussed in this presentation**

# Mexico City – what's achieved and remaining challenges




**AQ Management Programs – significant measures implemented**

- Extensive **AQ monitoring stations**
- **Emissions inventory** (updated 2 yrly)
- Air Quality **Standards** implemented

- **Transportation**
  - **removal of lead from gasoline** and its reformulation
  - mandatory **use of catalytic converter**s
  - **reduce sulfur content in diesel fuel**
  - reinforce **vehicle inspection and "no driving day"** rule
  - implement **air pollution contingency program**

- **Industrial and residential sectors**
  - **Increased use of natural gas** instead of oil
  - **LPG** for cooking and water heating
  - Promote **energy efficient buildings** and solar water heating
- Develop **Air Quality Forecasting System**
- Engage **Health sector** in evaluation of air pollution impacts
- Enhance **communication** with public and stakeholders

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

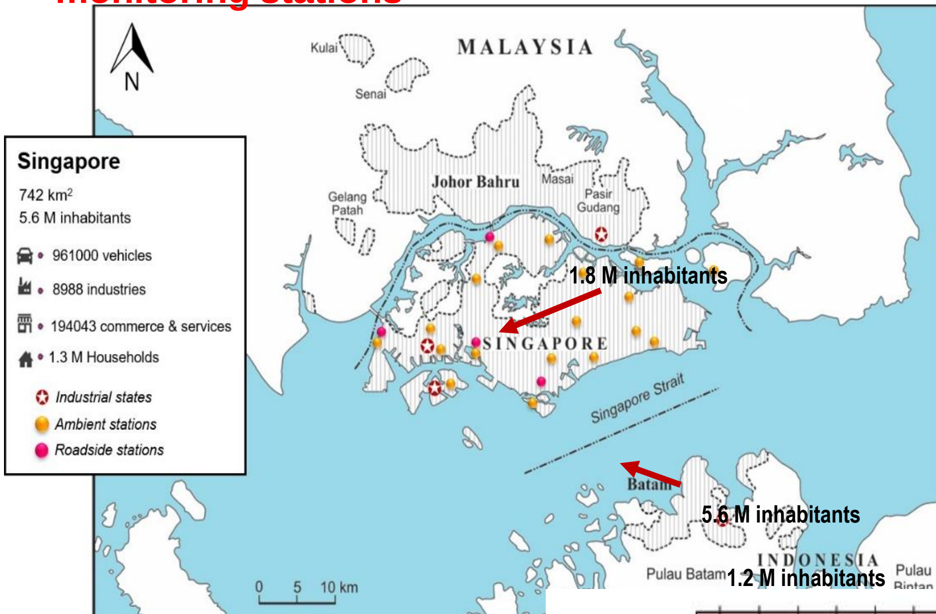
**Ongoing Challenges:**

Reduction in $O_3$ and PM slow

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

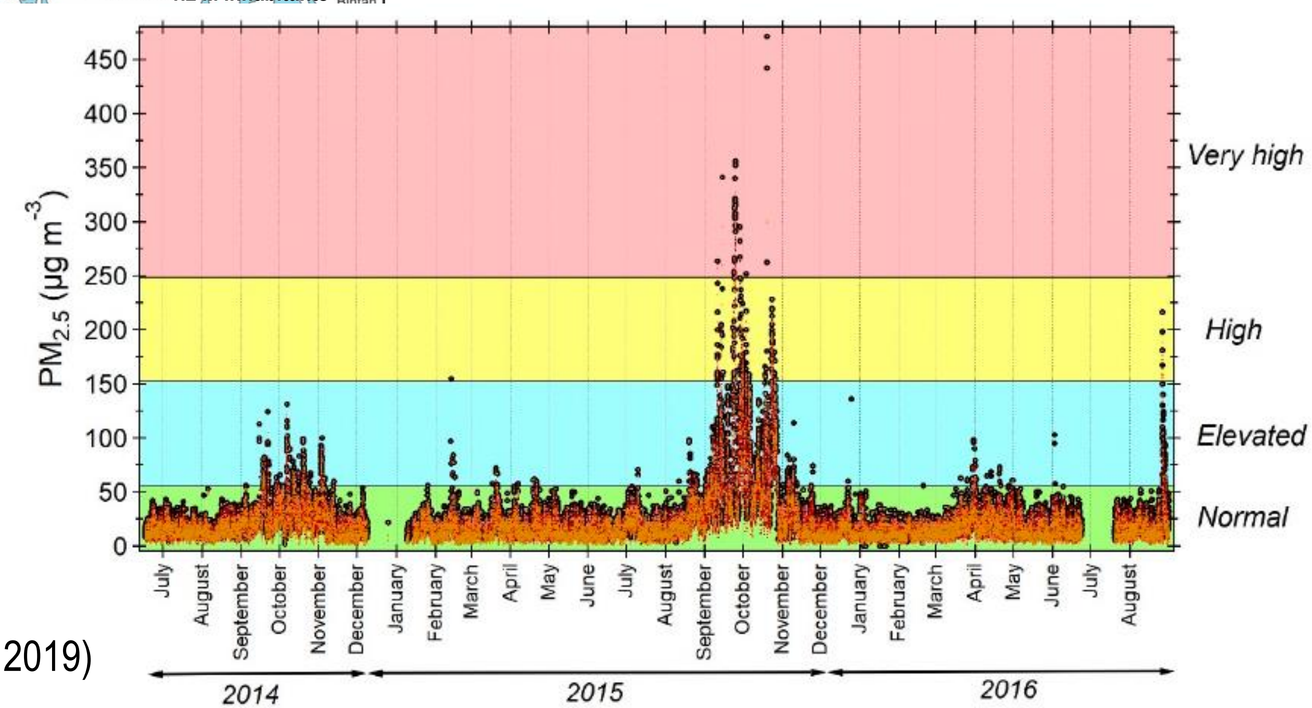
Yellow and red dots are locations of **ambient and roadside air quality monitoring stations**

# 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 Malaysian cities of Johor Bahru and Batam.
  - **Haze episodes** from neighboring Indonesia's wildfires

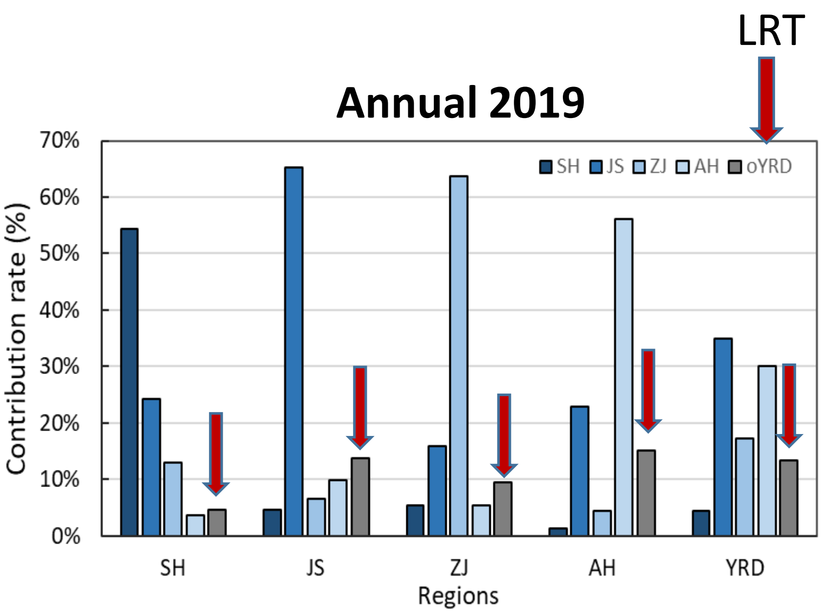
Map of Sijori Growth Triangle (total population = 8.6M) formed by the urban areas (shade area) of Singapore, Johor Bahru in Malaysia to the north and the Indonesia's island of Batam to the south.



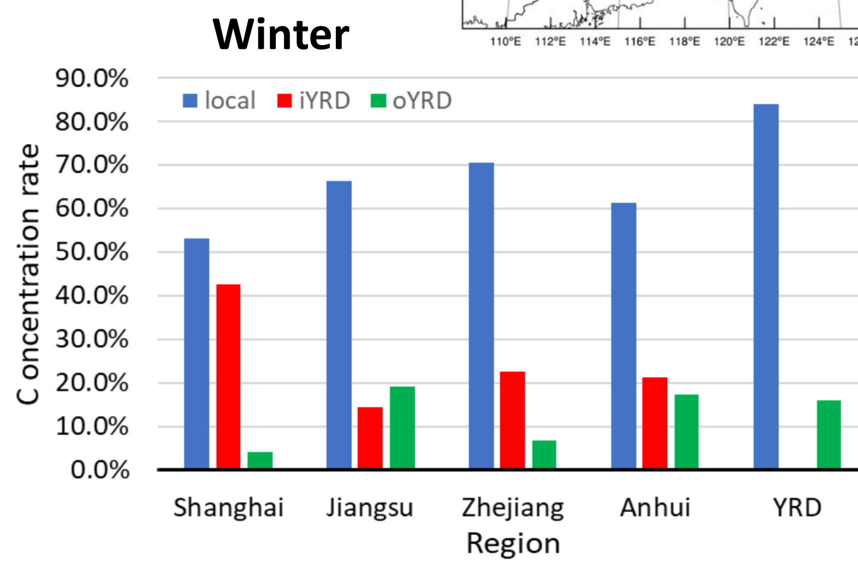

(Source: Molina et al., Atmosphere, 2019)

# WRF-Chem analysis of $PM_{2.5}$ concentration over the Yangtze River Delta (YRD) region (Shanghai, Jiangsu, Anhui and Zhejiang)


- **Local emissions** typically contribute 55-65% for $PM_{2.5}$ over YRD provincial regions, and **85% for YRD in 2019**
- Comparable transport contribution annually and in winter
- **Inner/mutual transport** in YRD (iYRD) contribution varies **~20 - 40%**
- **Relatively smaller cross-regional** (oYRD) transport
- **Local contributions to PM2.5 are dominant**




Source apportionment by WRF-Chem modeling in 2019



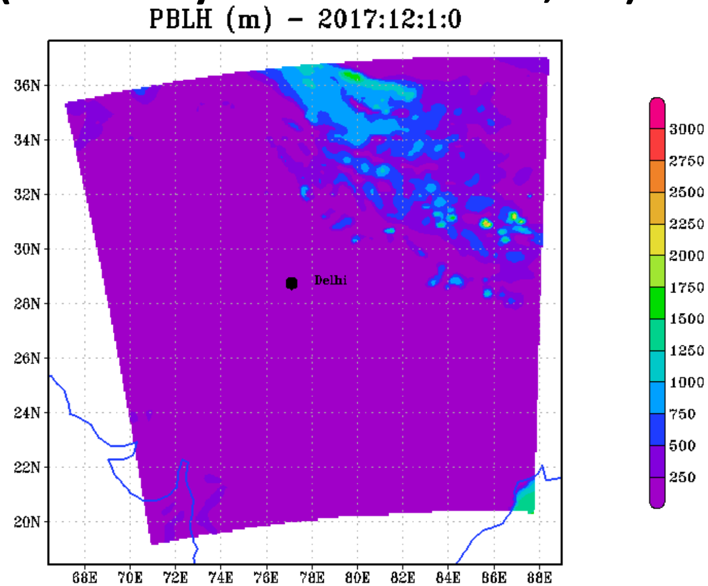

Source apportionment Nov. 2018-Feb. 2019

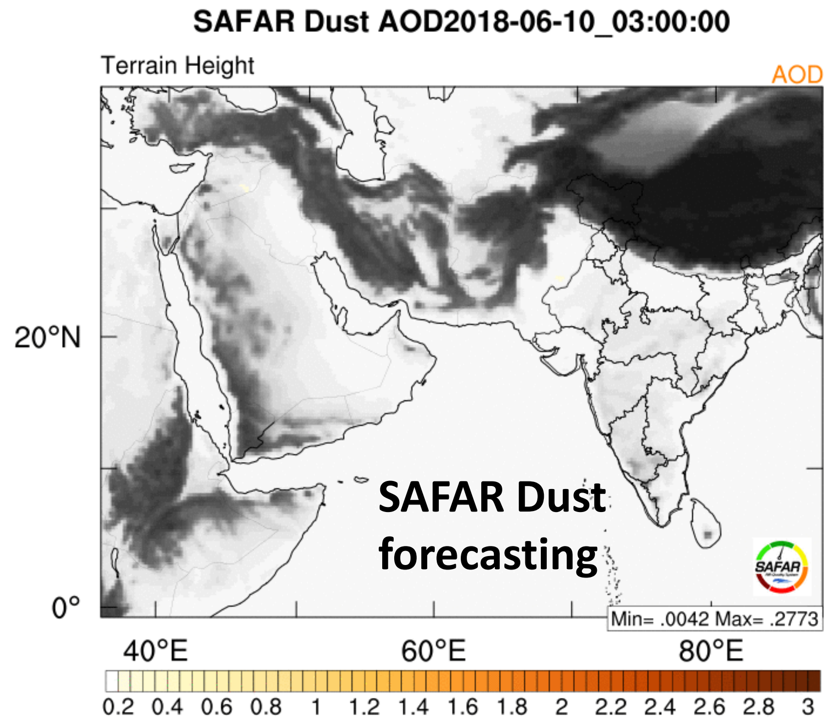
**Local emissions contribute nearly 2/3 of PM2.5 and LRT accounts for 1/3**

Source: Jiangou Tan, CMA

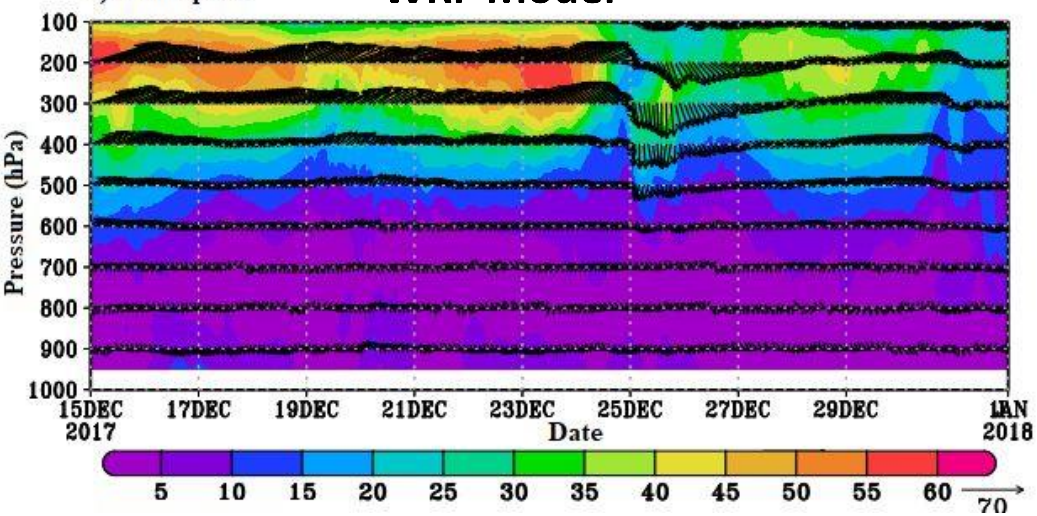
# PROMOTE: Process analysis and forecasting for India
# Understanding Long Range Transport affecting Delhi

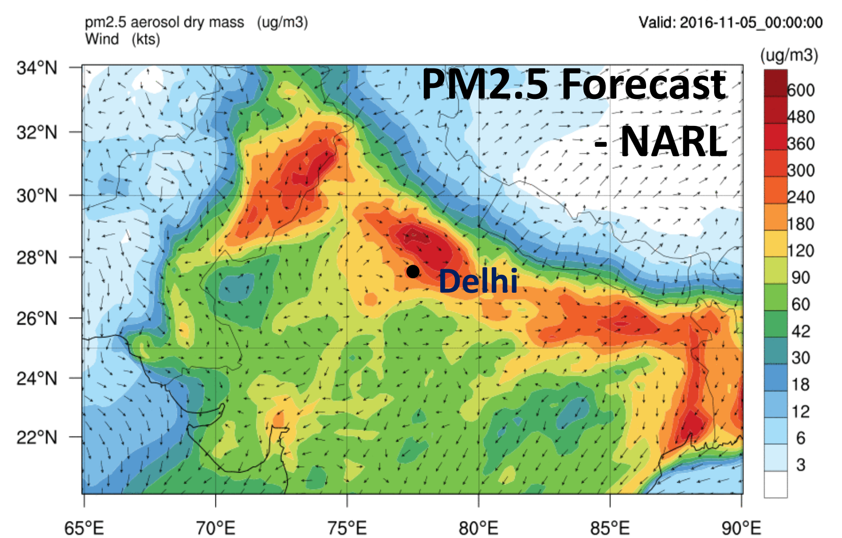
**PBL evolution over Delhi – WRF (University of Hertfordshire, UK)**



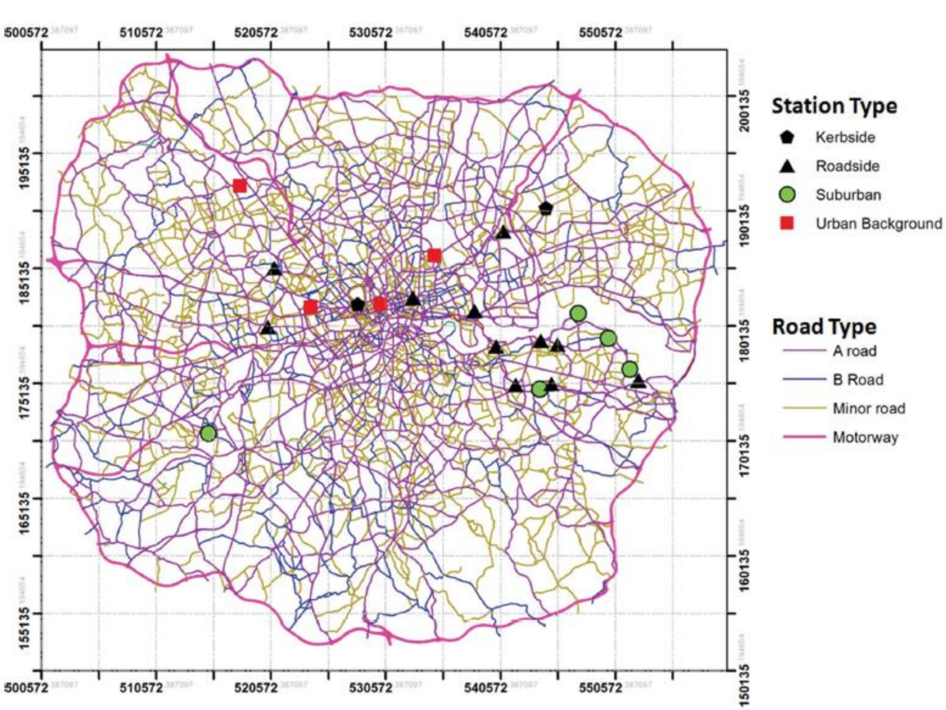

**WRF Model**

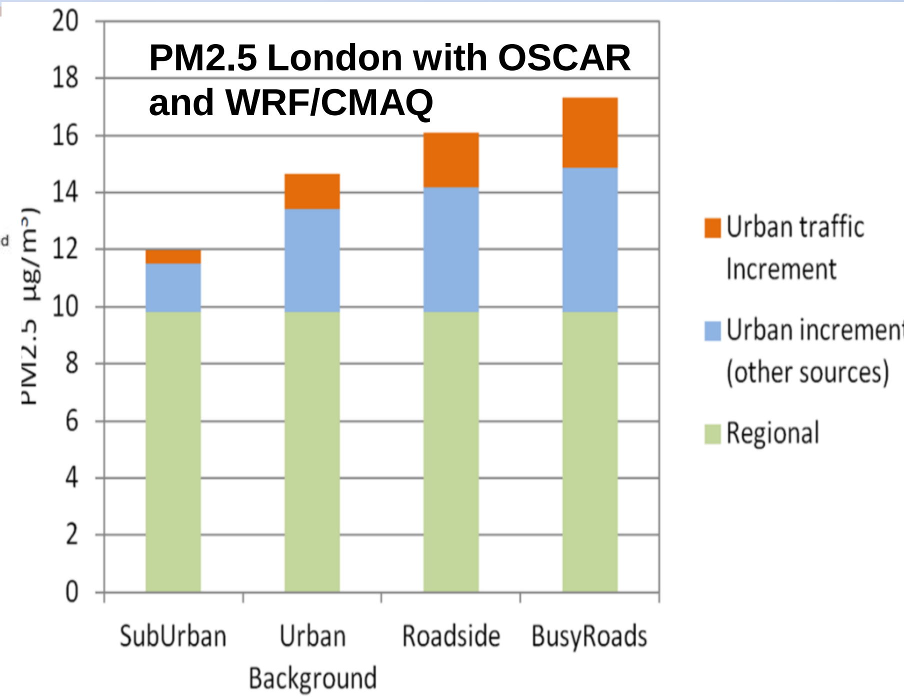


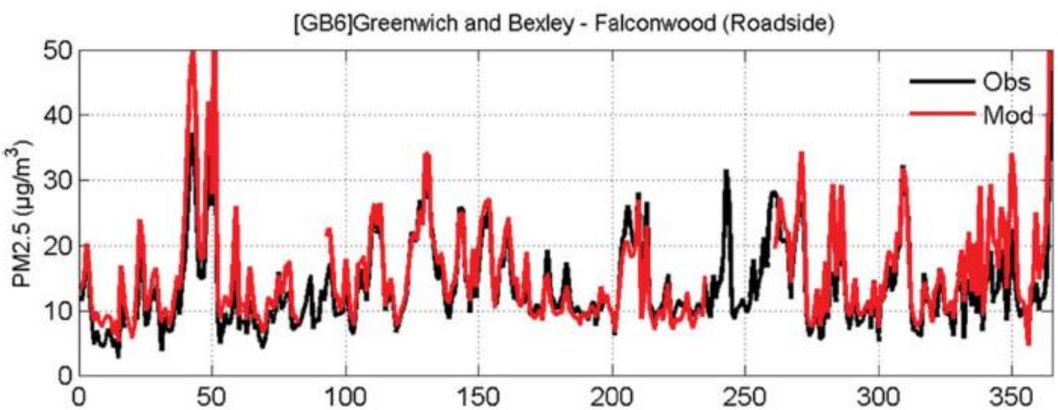



# Local and regional contributions to Particulate Matter

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




**PM2.5 Concentrations at a roadside (annual means)**:
Regional contributions ~ 60-80%
Other Urban BG ~ 15-30%
Roadside traffic ~ 5-20%

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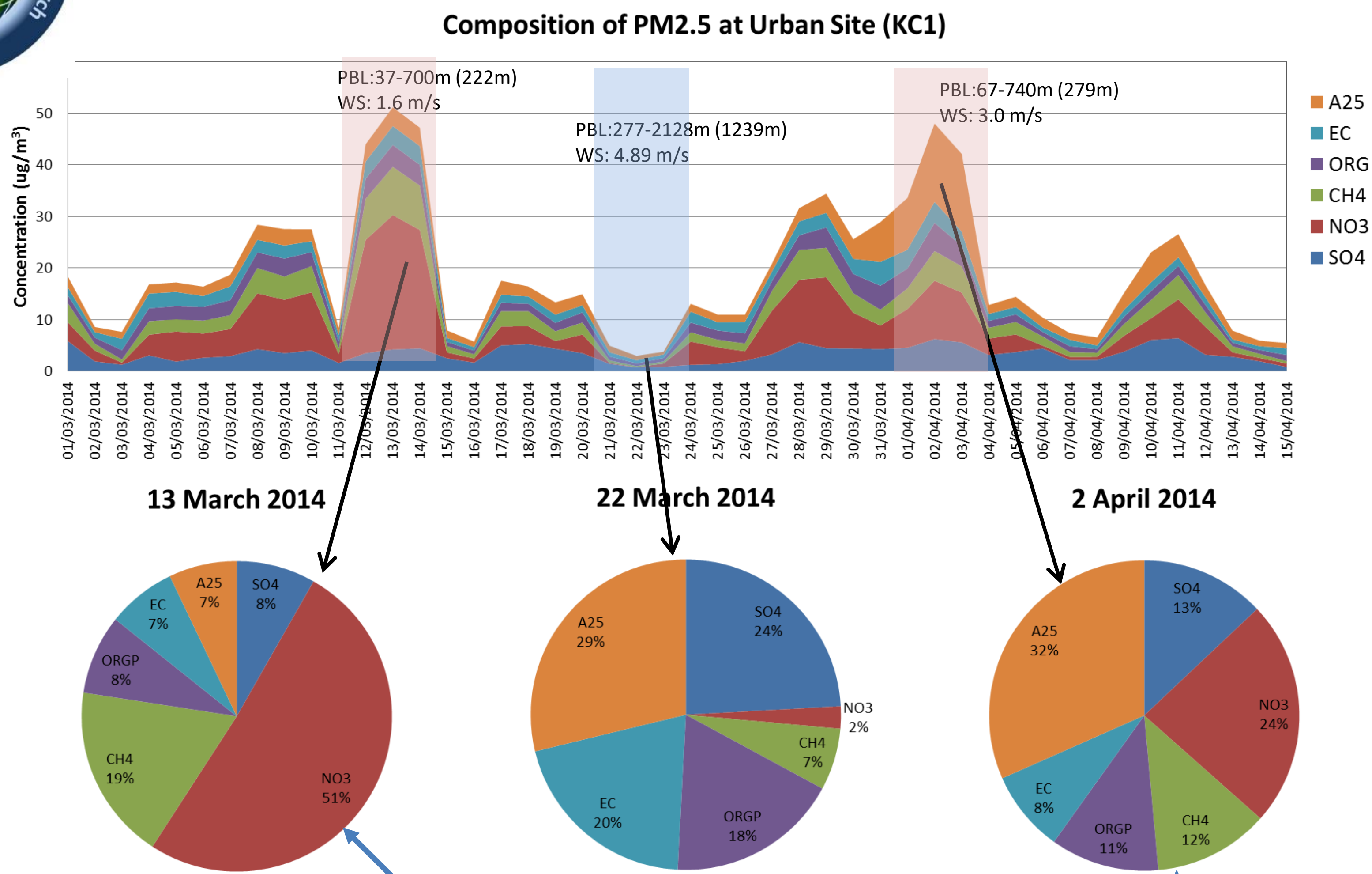
# PM2.5 Episode (London Urban)
# Not just PM mass!




**Similar PM2.5 levels at episodes but very different composition**

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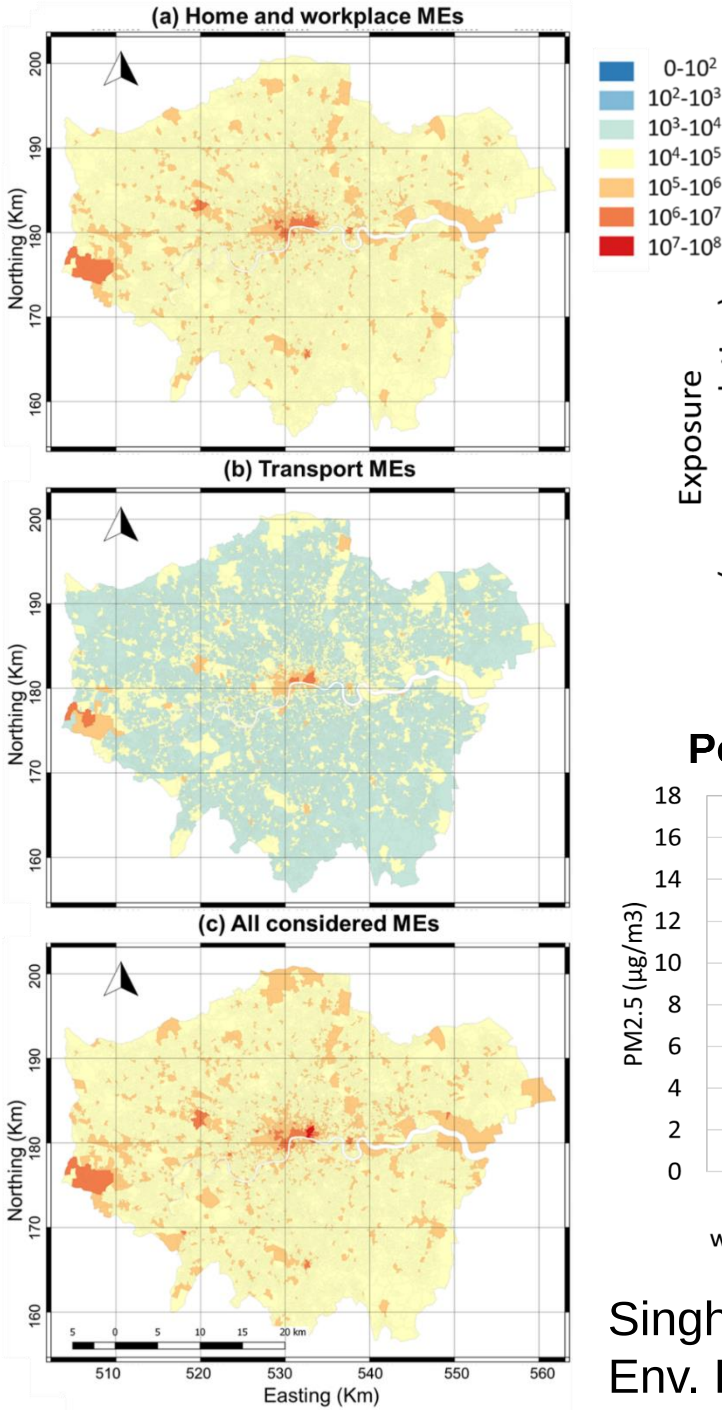
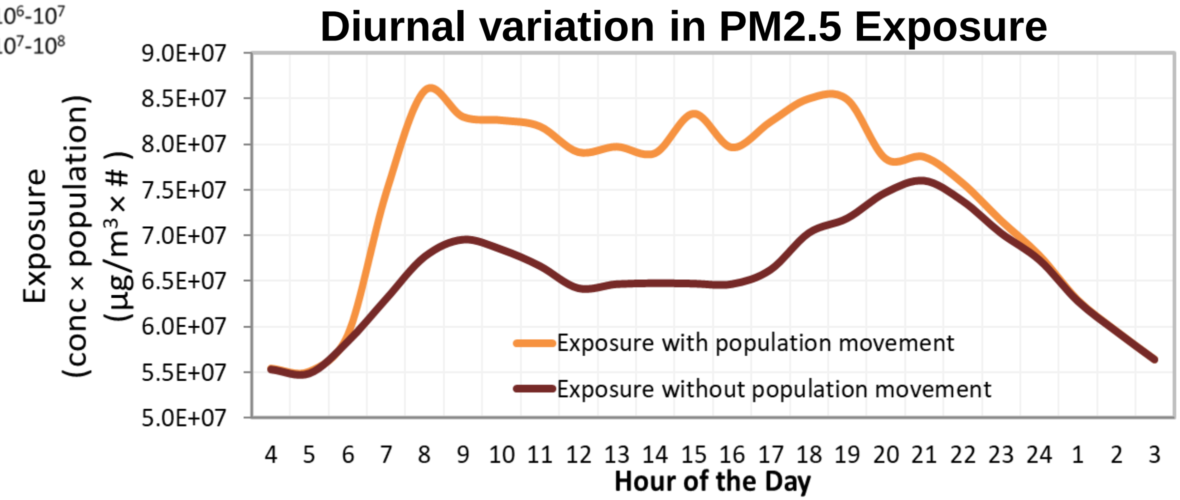
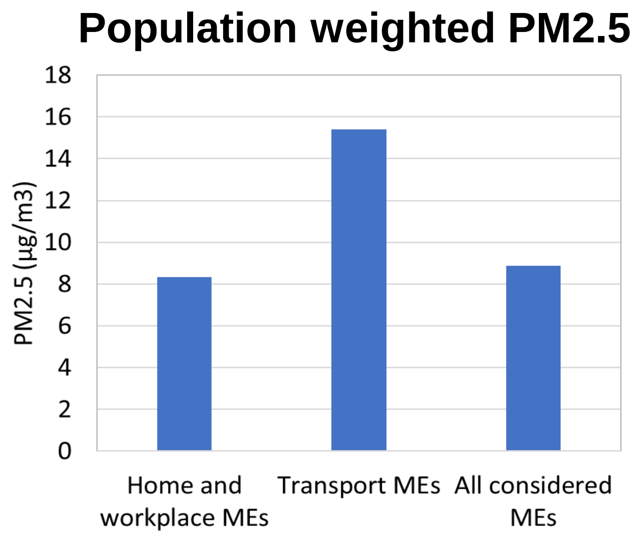
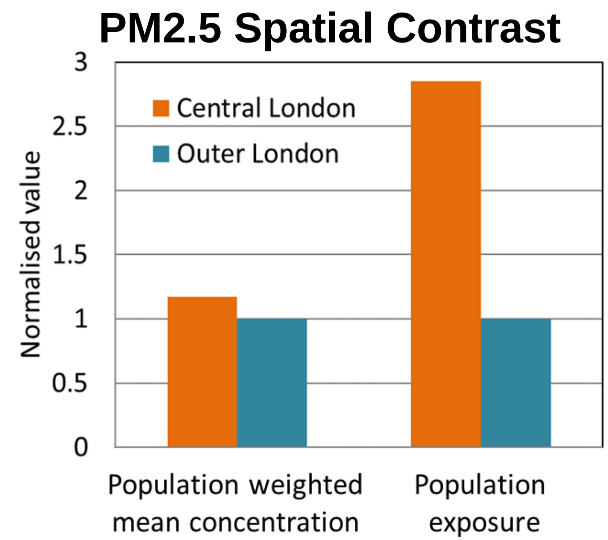
# EXPOSURE - Spatial and temporal variation in PM2.5 over London




Singh et al (2020)
Env. Pollution

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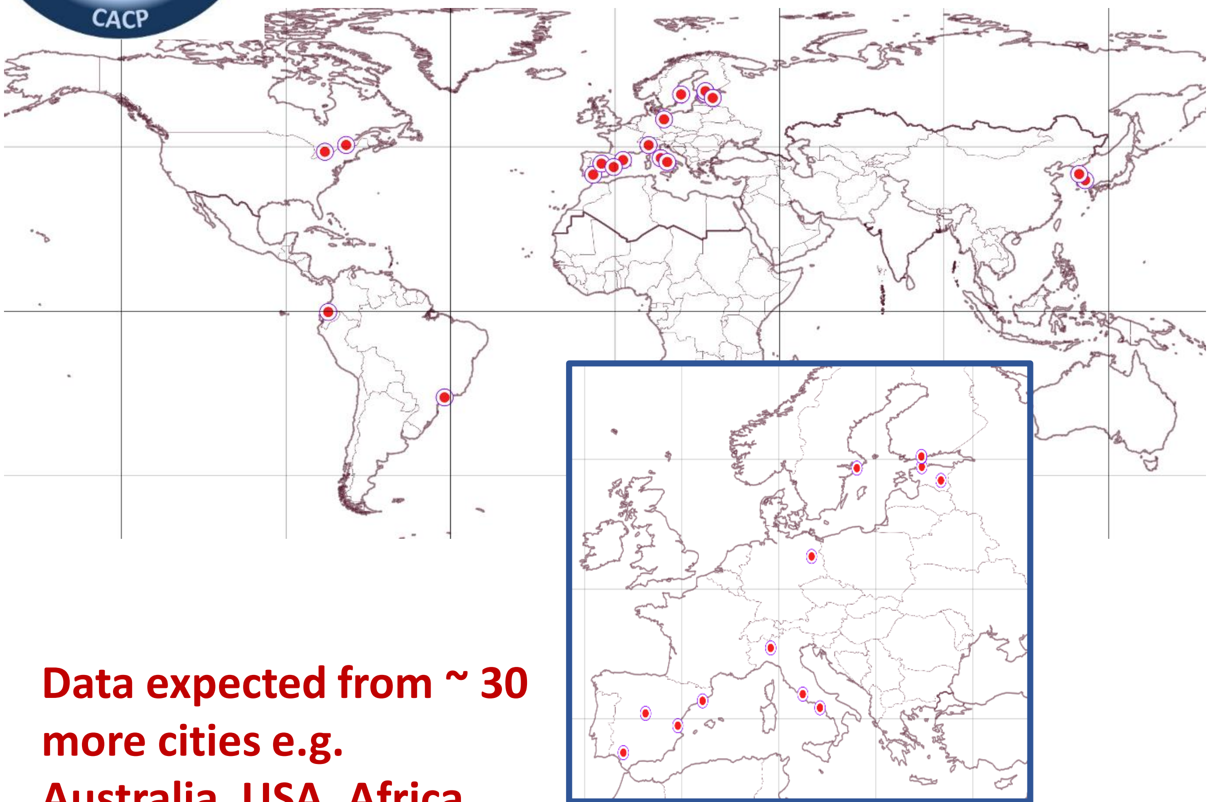
# WMO/GAW Observational and Modelling Study of the Impact of COVID Lockdown Measures on Air Quality in Global Cities

## Contributions from many global contributors

# Global Cities - First phase of analysis



| City | Country | Continent |
|---|---|---|
| Barcelona | Spain | Europe |
| Berlin | Germany | Europe |
| Bogota | Colombia | South America |
| Daegu | South Korea | East Asia |
| Helsinki | Finland | Europe |
| Madrid | Spain | Europe |
| Madrid2 | Spain | Europe |
| Milano | Italy | Europe |
| Montreal | Canada | North America |
| Naples | Italy | Europe |
| Quito | Ecuador | South America |
| Rome | Italy | Europe |
| Seoul | South Korea | East Asia |
| Sevilla | Spain | Europe |
| Stockholm | Sweden | Europe |
| São Paulo | Brazil | South America |
| Tallinn | Estonia | Europe |
| Tartu | Estonia | Europe |
| Toronto | Canada | North America |
| Valencia | Spain | Europe |

**Data expected from ~ 30 more cities e.g. Australia, USA, Africa, India, China, Latin America**

# Lockdown periods across different cities (Two submissions from Madrid)

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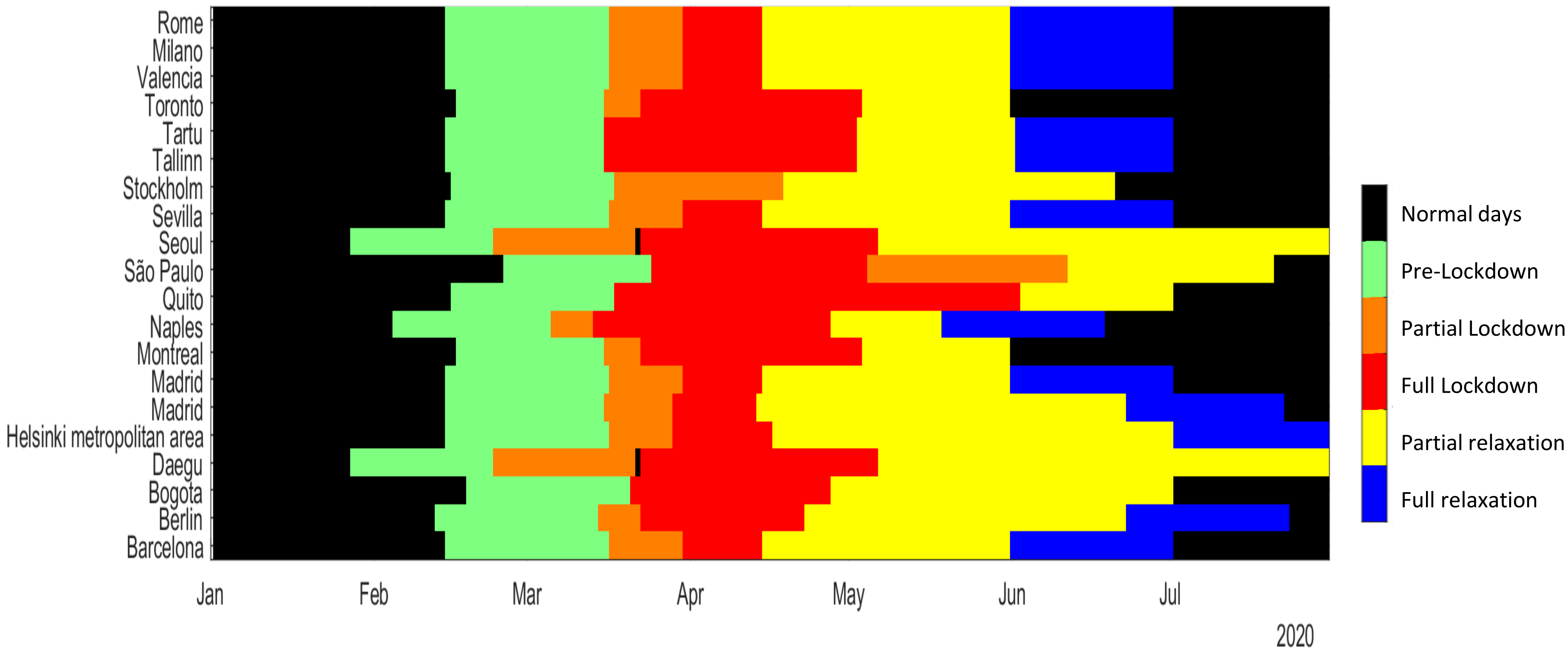
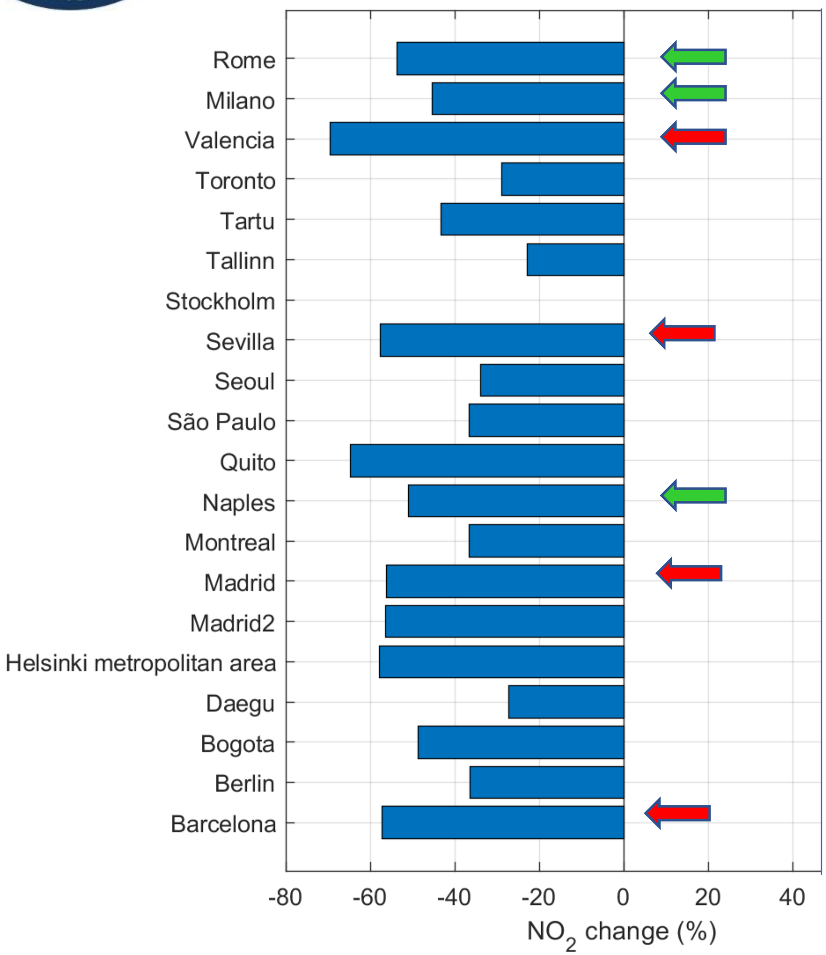
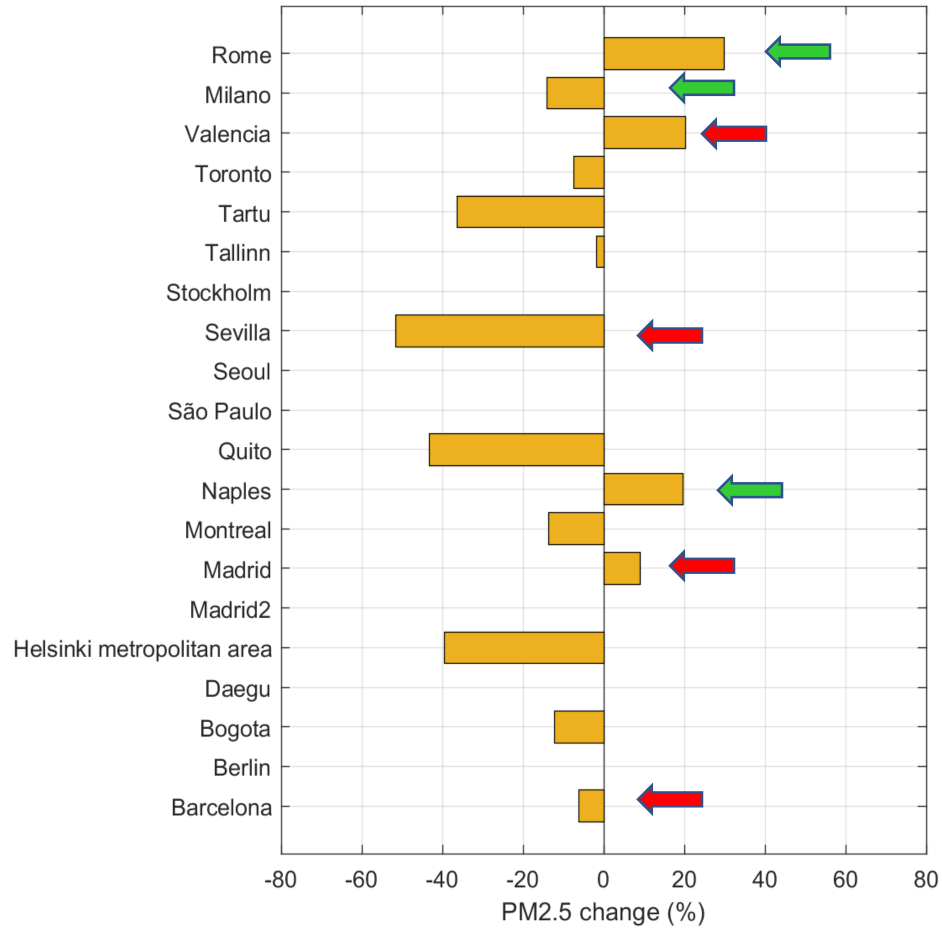


# Percentage change in NO2 from pre-lockdown to full lockdown

Spanish cities ← Italian cities ←




**Consistent reduction in NO2**

**Greater variability in PM changes**

# Change in PM2.5 and NO2 for different periods

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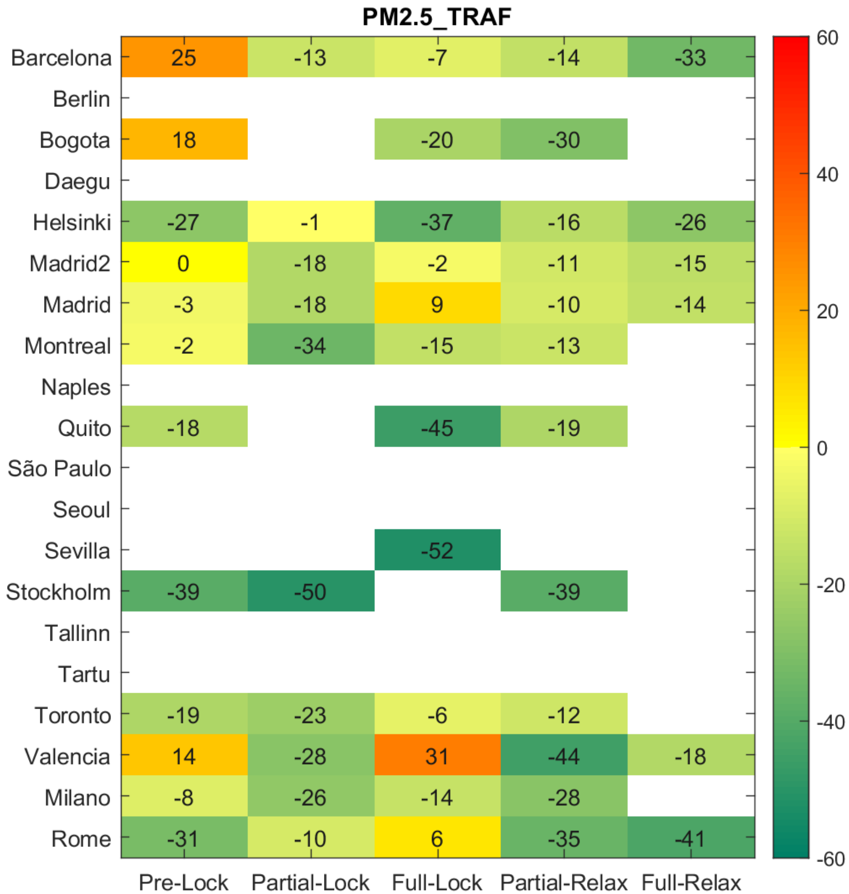


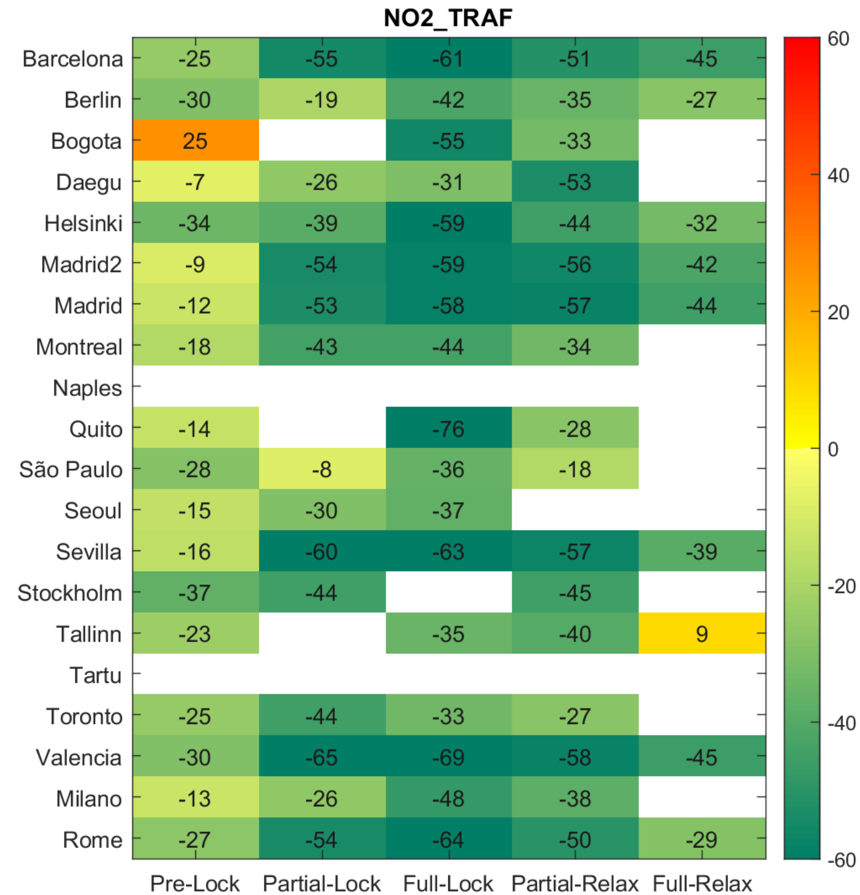


**Less clear trend for PM2.5 across cities**

**Clearer trend for NO2 across most cities**

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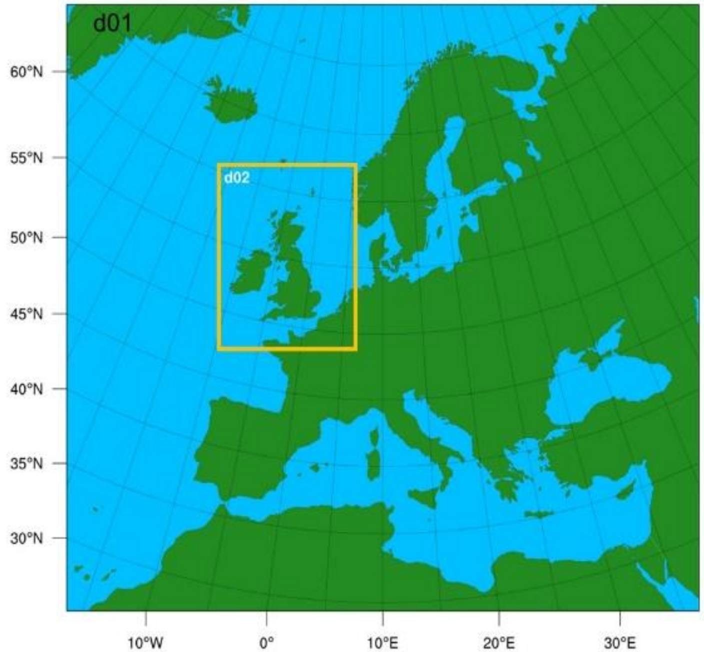
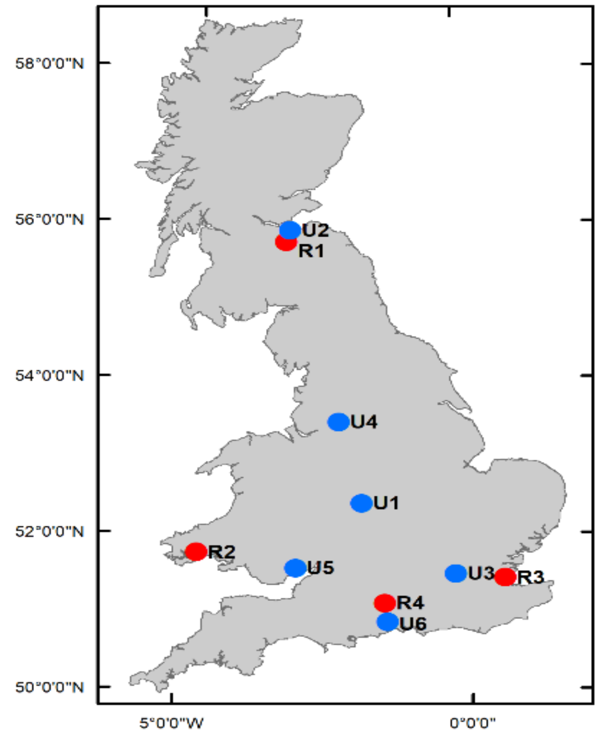
# WRF-CMAQ modelling analysis




WRF/CMAQ model domain based on the air quality forecasting system




Location of AURN measurement stations used for model evaluation

| Station name | Type | Label |
|---|---|---|
| Auchencorth Moss | Rural | R1 |
| Narberth | Rural | R2 |
| Rochester Stoke | Rural | R3 |
| Chilbolton Observatory | Rural | R4 |
| Birmingham Acocks Green | Urban | U1 |
| Edinburgh St Leonards | Urban | U2 |
| London N. Kensington | Urban | U3 |
| Manchester Piccadilly | Urban | U4 |
| Newport | Urban | U5 |
| Southampton Centre | Urban | U6 |



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# Predicted changes during the lockdown period at URBAN locations over the UK

**Lockdown period 24 March to 26 April 2020**

**Scenarios:**
1 – Overall emission reductions
2 – reduction in road traffic only

Using Marc Guevara et al., ACPD 2020

**Most of the changes can be attributed to reductions in road traffic emissions**

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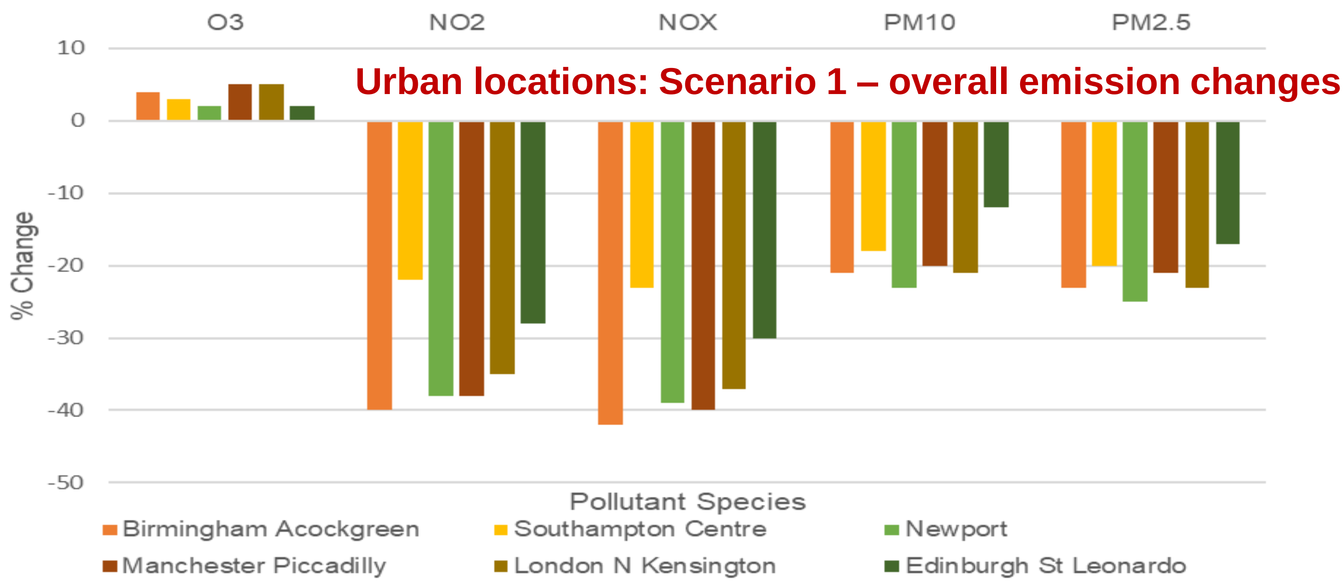
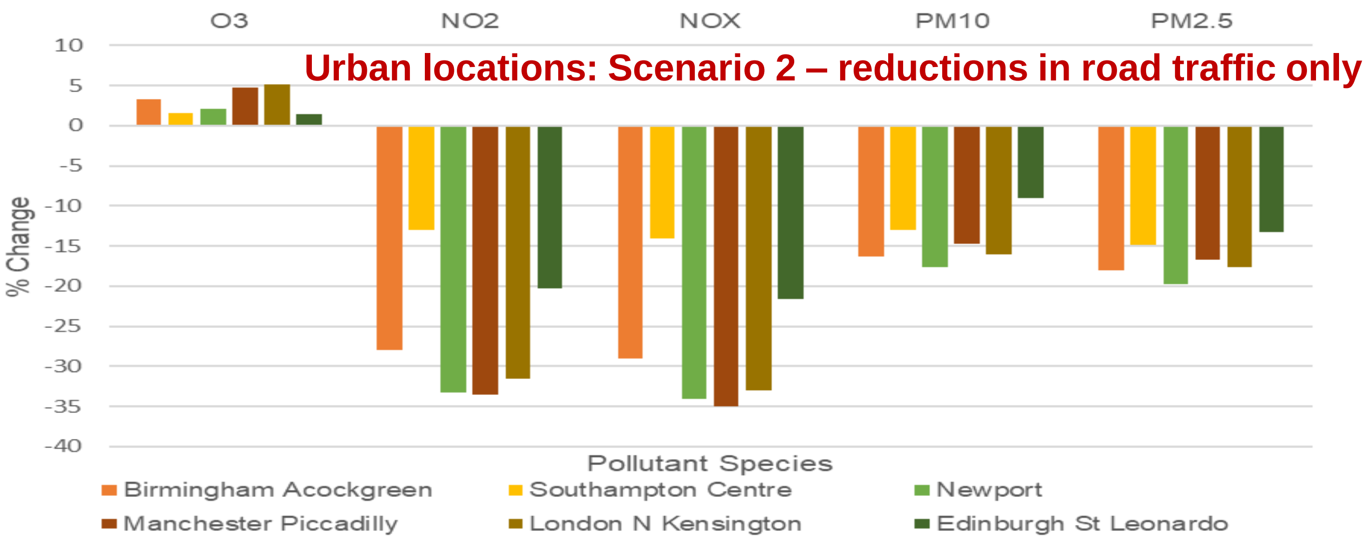
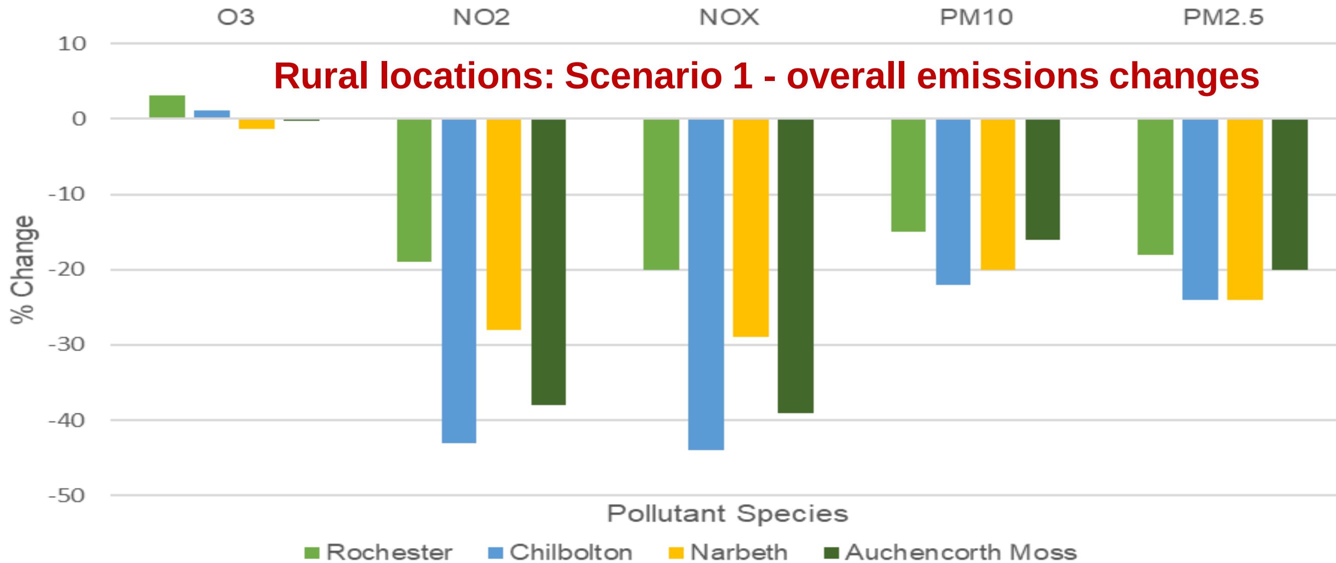
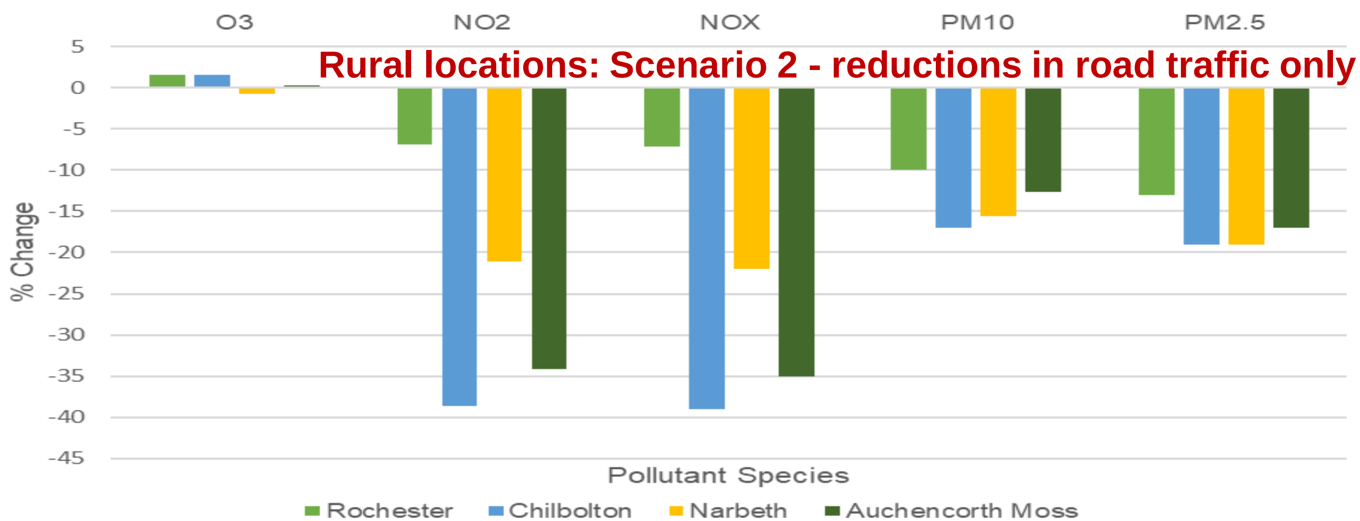


# Predicted changes during the lockdown period at RURAL locations over the UK

## Lockdown period 24 March to 26 April 2020




**Most of the changes can be attributed to reductions in road traffic emissions**

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# Predicted percentage spatial changes Scenario 1 (overall emission changes)

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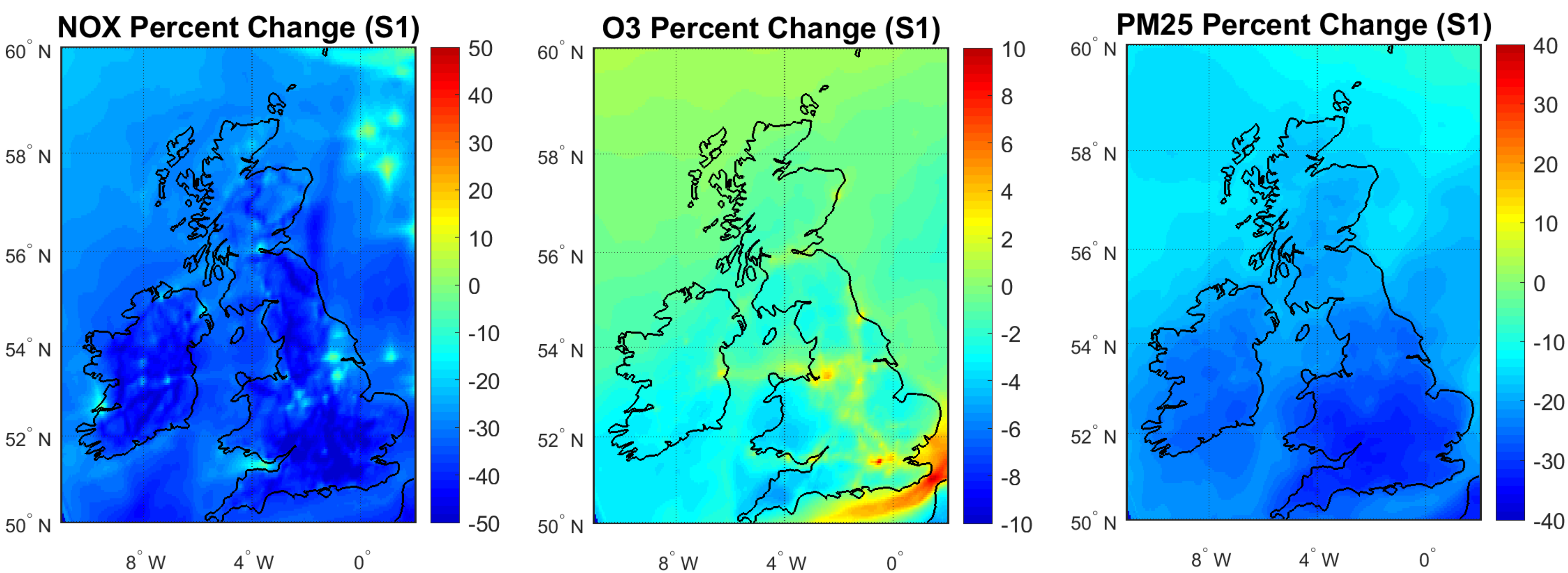


Mean modelled percentage changes in NOx, $O_3$ and $PM_{2.5}$ over the UK during the lockdown period (24 March – 26 April 2020) based on Scenario 1 – overall emissions changes

# Concluding remarks

- **Global challenges facing cities** – more extensive monitoring, improved emission inventories, need to benefit from advances process based modelling approaches

- **International coordination** efforts such as EPCAC will be important to develop best practice and what works under what conditions

- **Coordinated AQ-COVID study**: First observational analysis shows a reduction of 20-60% in NO2 and up to 40% in PM2.5 in cities but with regional differences e.g. in some cities there is an increase in PM2.5

- **UK modelling analysis** indicates similar reductions in NO2 and PM2.5 but increases in $O_3$ in urban areas and around airports

- Modelling analysis suggests most of the **changes during lockdown can be attributed to reduction in road traffic emissions**

# Remarks on an EPCAC air quality modelling study

- **Multiscale approach** - Air quality in cities is determined by **both local and regional contributions** which is **critical** to reach end goal of air quality improvement for the whole city
- **Multiannual study** to provide robust conclusions – 3-5 years
- **Multiple pollutants and sources** – e.g. NO2, PM2.5, PM10, O3, PM components
- **Include source apportionment analysis** – e.g. PM composition is different during different seasons and usual/episodic conditions
- **Sensitivity to emissions** – change emissions for same met regimes and fix emissions for different met conditions
- **Model evaluation** – include process based (diagnostic) approach to support operational and dynamical metrics supported by observations