

Sources and Challenges in Regulating Fine Particles (PM_{2.5}) in UK Cities



UCL

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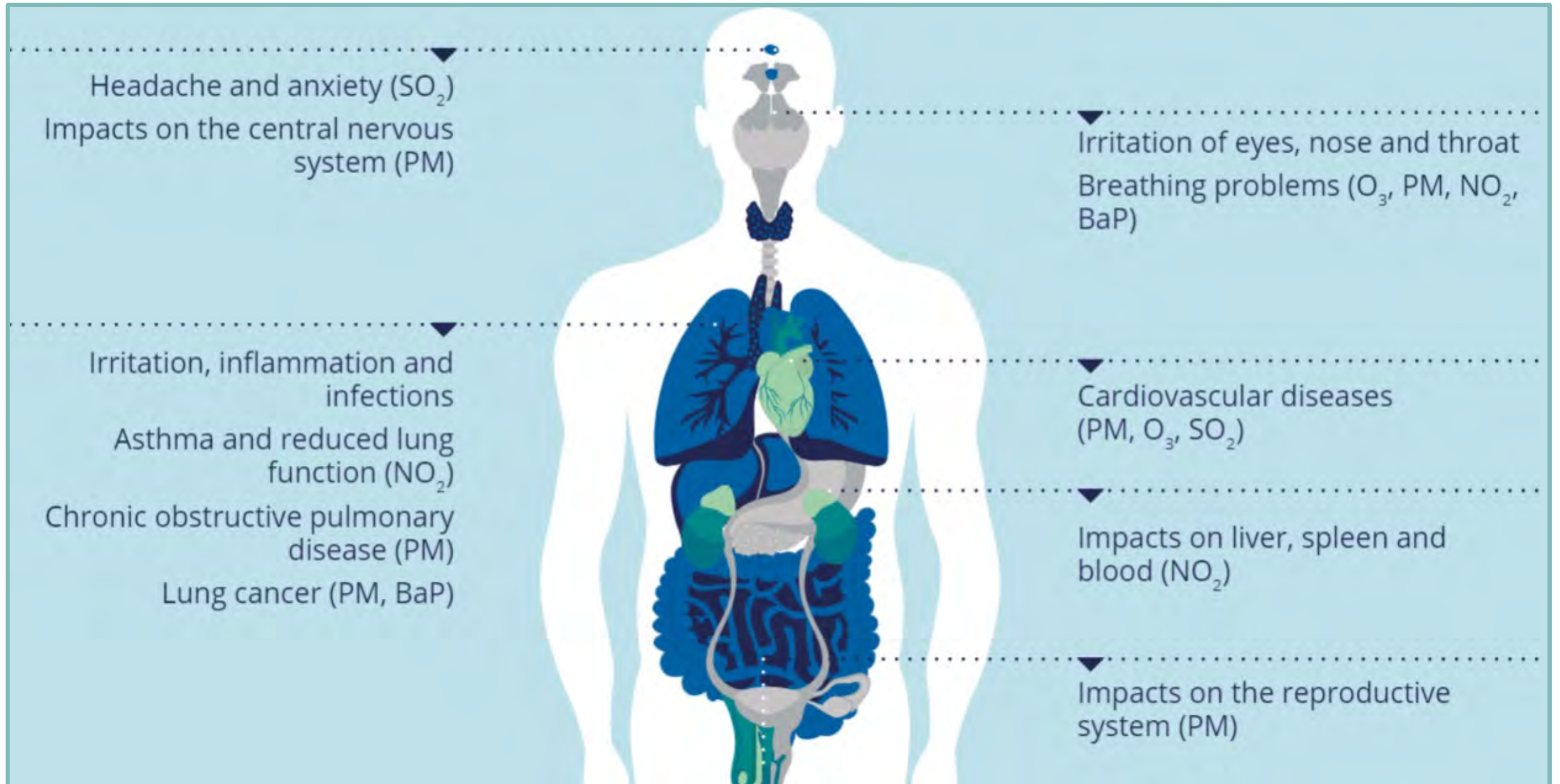
Roland Leigh
Jordan White

Ella Adoo-Kissi-Debrah



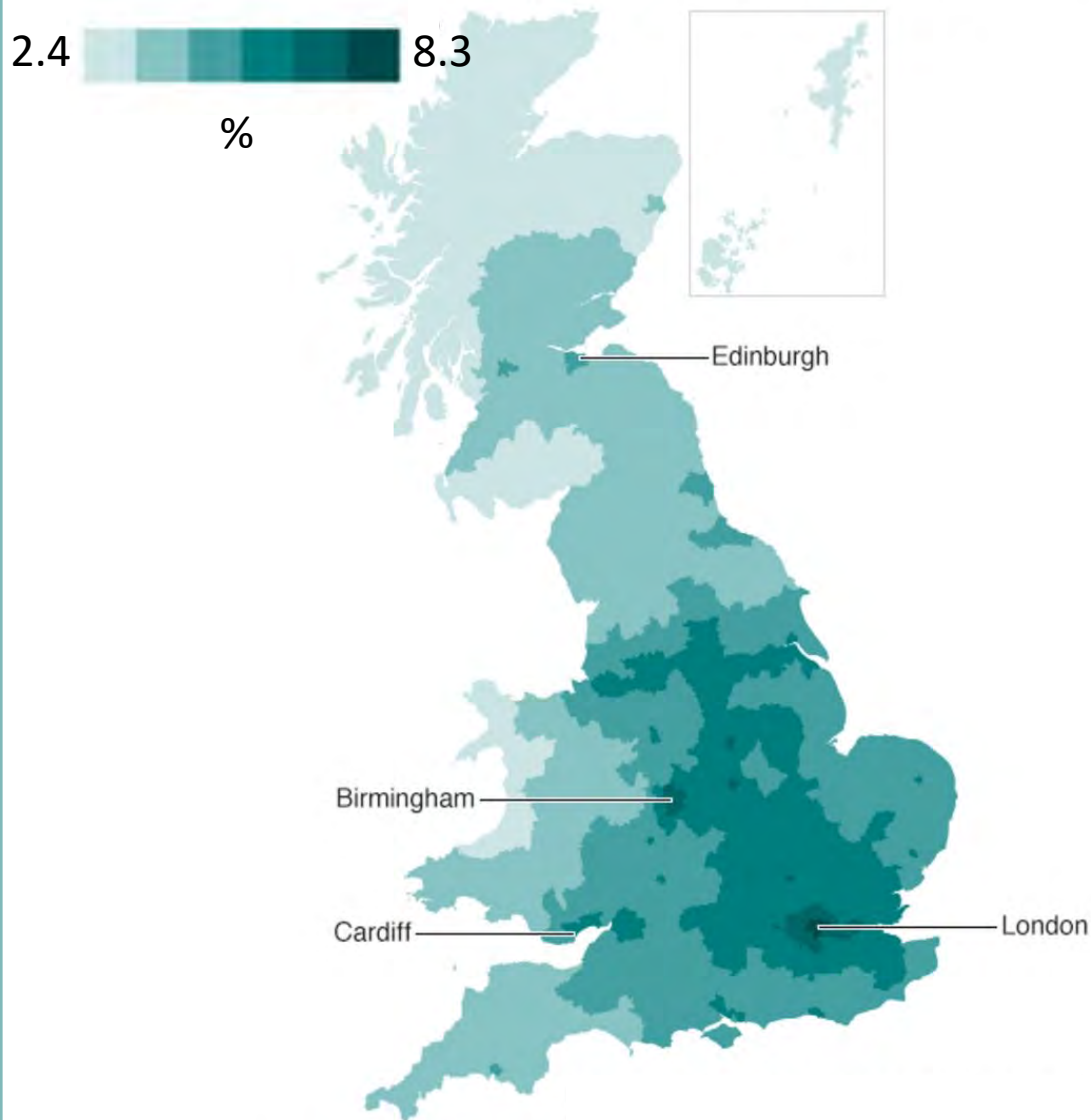
Source – Ella Roberts Foundation (<http://ellaroberta.org/about-ella/>)

Air pollution has negative impacts on nearly all major organs and systems of the body



Air pollution is major public health burden in the UK

Percentage of deaths attributable to air pollution



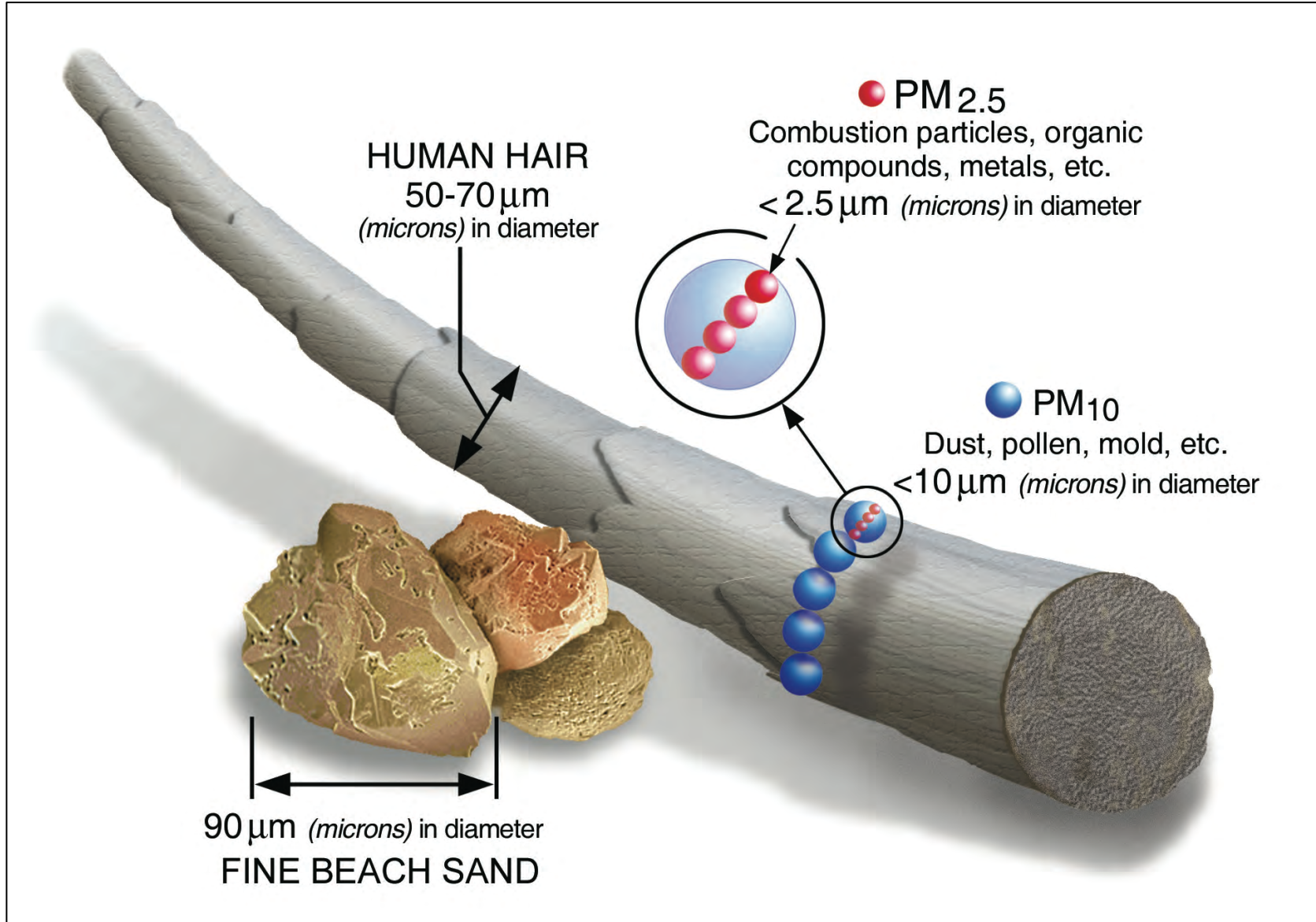
Highest mortality rates in polluted and populated regions (e.g. London)

Annual mortality rates...

- UK = 30,000-40,000
- Europe = ~400,000
- Globally = 2-8 million

Most important pollutant are Fine Particles (PM_{2.5})

Fine Particles



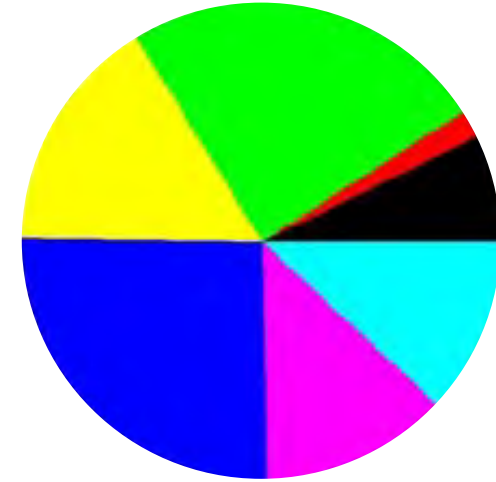
Source – US Environmental Protection Agency (EPA)

Particles are a mix of components that persist for days

Direct emission
of PM_{2.5}
(primary)

Emission of gas-phase
precursors
(secondary)

PM_{2.5} includes a mix of components



Black carbon **primary**

Sulfate

Nitrate

Ammonium

secondary

Other inorganics

Organic aerosols **primary+secondary**

PM_{2.5} includes local and distant sources (long atmospheric lifetime)

Regulatory Framework for Air Pollution in the UK

International Bodies

World Health
Organisation (WHO)



World Health
Organization

Gothenburg
Protocol



International Maritime
Organisation (IMO)



National Government

Department for Environment,
Food, and Rural Affairs (DEFRA)



Department
for Environment
Food & Rural Affairs

Local Authorities

City
Councils



Camden



Leicester
City Council

Setting Air Quality Standards and Guideline concentrations

- WHO – $5 \mu\text{g m}^{-3}$
- UK – $25 \mu\text{g m}^{-3}$

Setting of National Total Emission Ceilings

Setting of Sulfur (S) and Nitrogen (N) content of ship fuel

Monitoring Compliance with Standards

Designation of Local Air Quality Management Areas (LAQMAs)

- Develop and enforce air quality plan
- Often targets fossil fuel combustion

Ultra low
emission

ULEZ

ZONE

At all times



Operating 24/7

ULEZ central London from 8 April 2019

in the same area as
the Congestion Charge

ULEZ extension to inner London from 25 Oct 2021

up to North and South
Circular roads, including
existing central London zone
(all vehicles)



LEZ London-wide from 26 Oct 2020

(lorries and other
vehicles over 3.5T)



Greater London Authority
Boundary



For a full list of affected vehicles see tfl.gov.uk/ulez

Sources of UK PM_{2.5}

Traffic



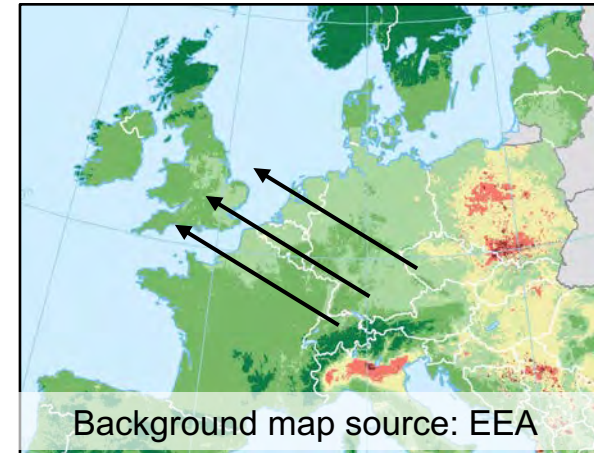
Agriculture



City



Regional



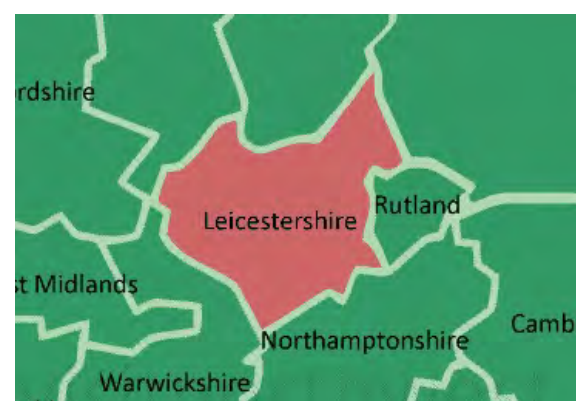
Shipping



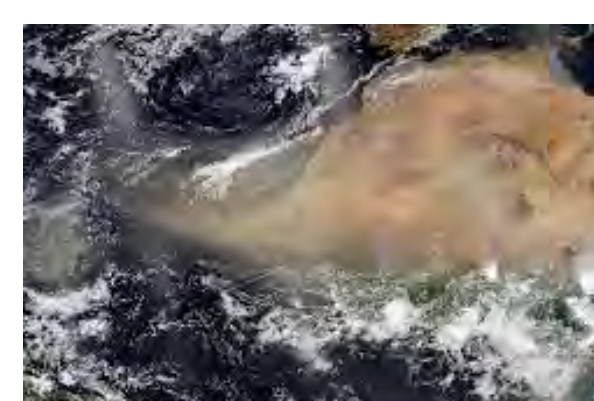
Construction



County



Global



Vieno et al. (2014); Vieno et al. (2016); Harrison et al. (2021), Fuller et al. (2014); Graham et al. (2020); Jiang et al. (2020); Wang et al. (2020).

Research Questions and Methodology Overview

RQ) What regions and sectors are the biggest contributors to PM_{2.5}?



Method #1 – Atmospheric modelling (UK-wide)

Eloise A Marais
Jamie M Kelly



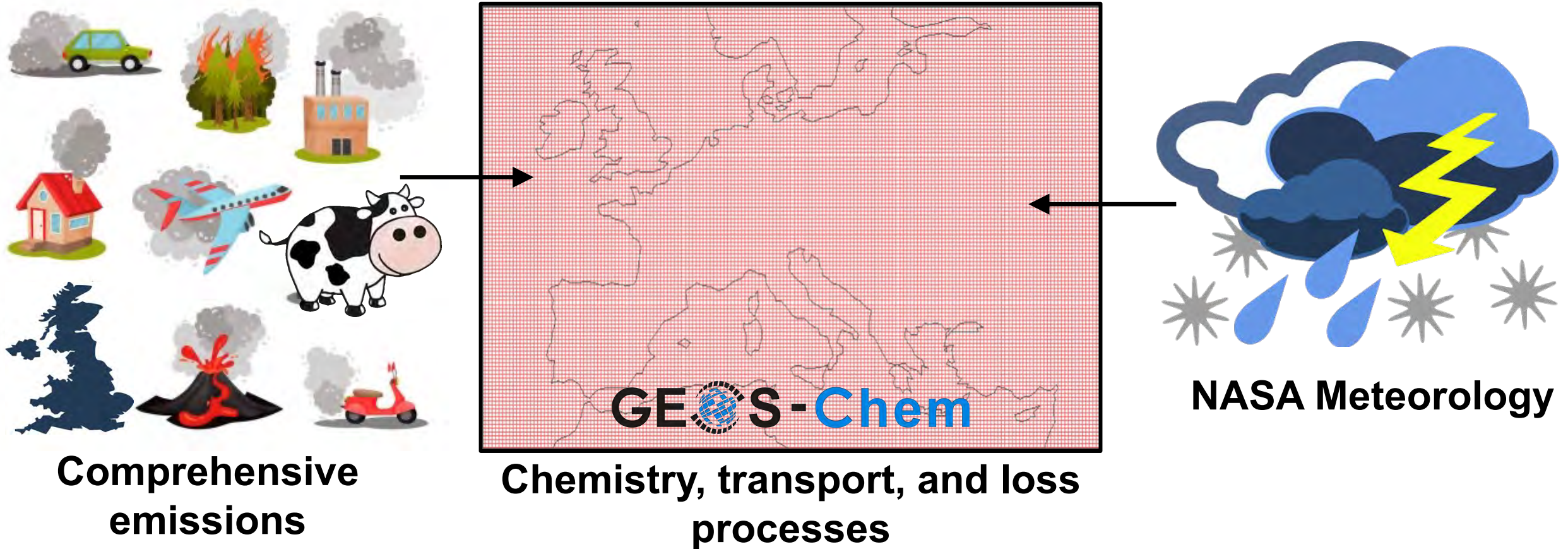
Method #2 – Low cost sensors (Leicester)

Roland Leigh
Jordan White



Simulate $\text{PM}_{2.5}$ with the 3D Model GEOS-Chem

3D Atmospheric Chemistry Transport Model

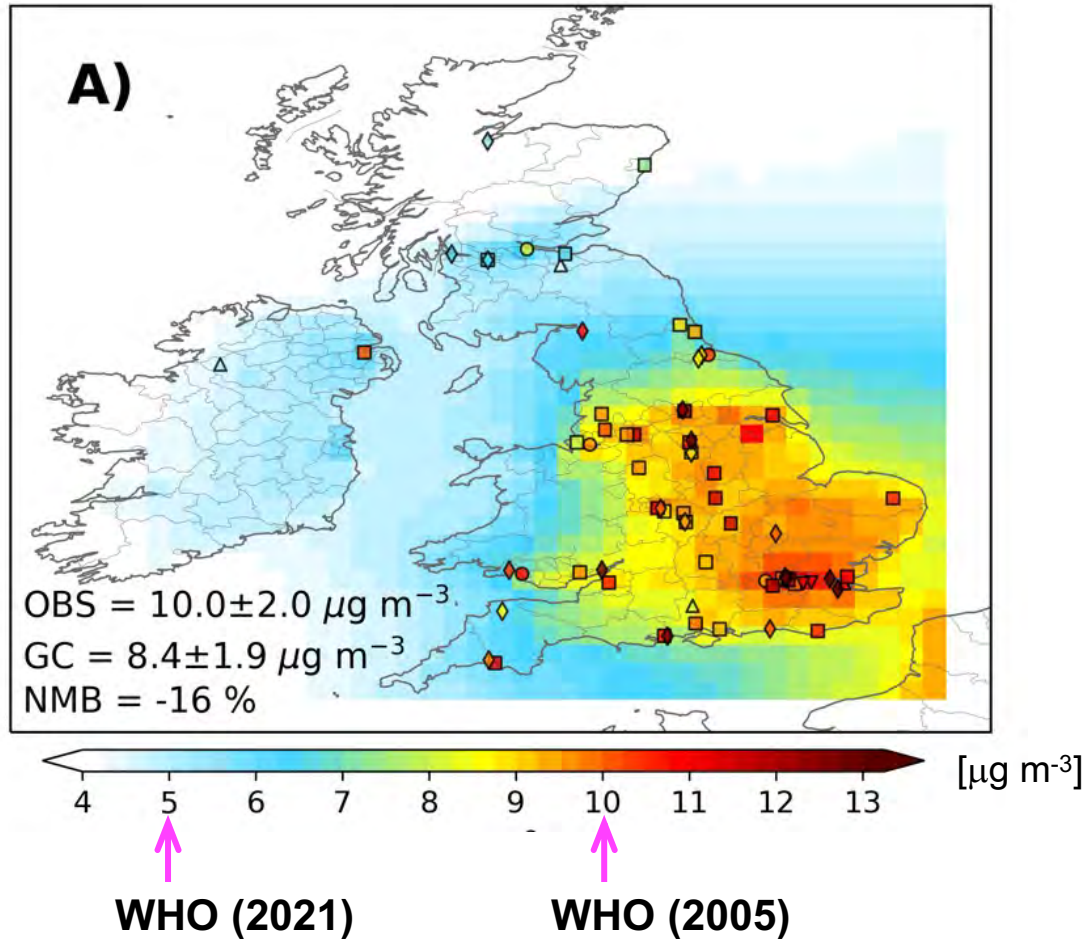


GEOS-Chem manual: <http://acmg.seas.harvard.edu/geos/>

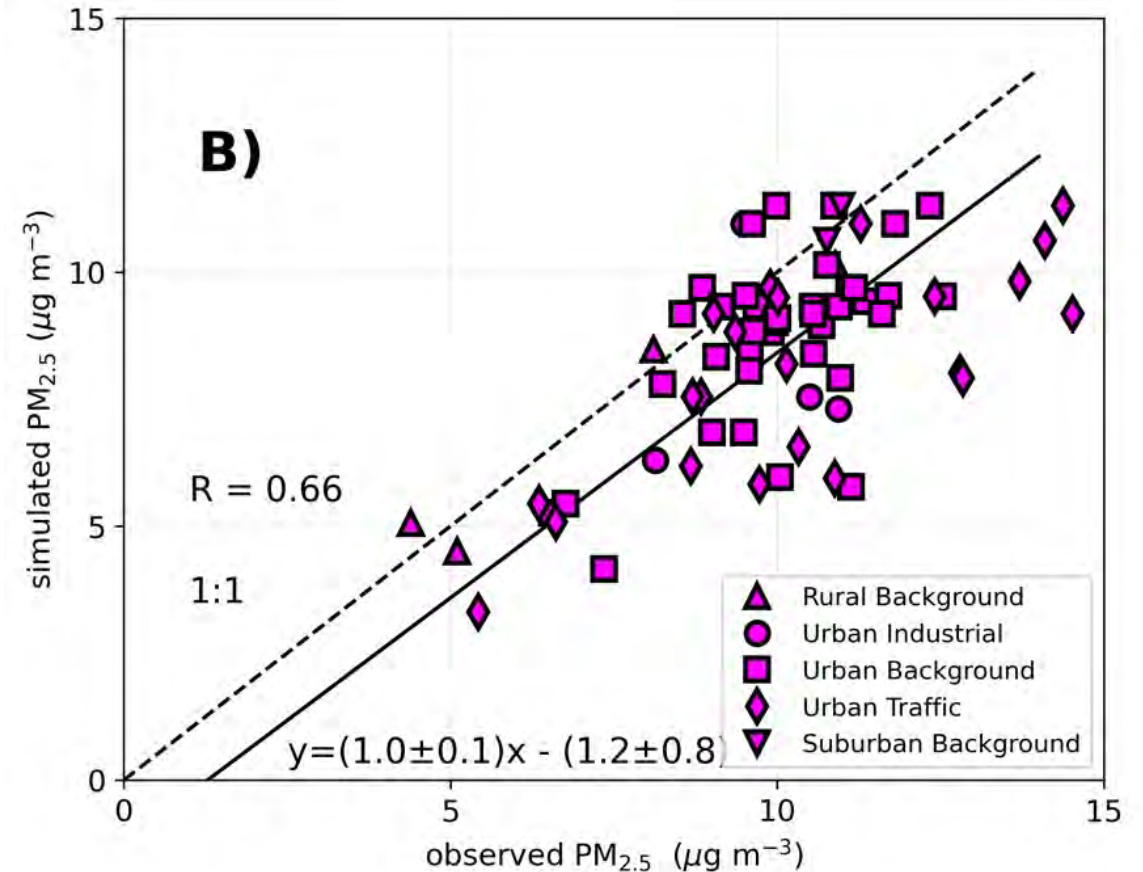
Assess Validity of Model using Reference Monitors

Use total PM_{2.5} observations from the Automatic Urban and Rural Network (AURN) to assess model

Comparison of annual mean surface concentrations of PM_{2.5} for 2019



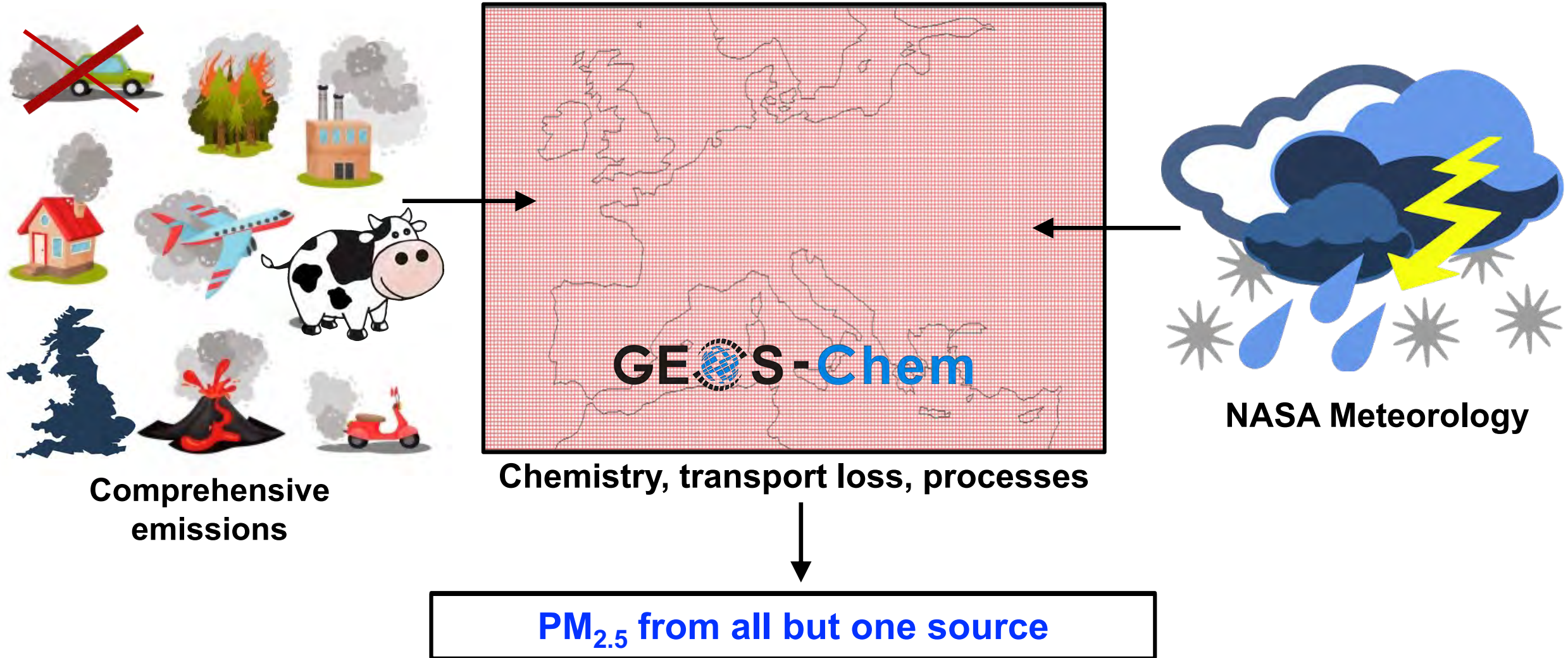
74% of UK exceeds updated WHO guideline



Consistent spatial pattern ($R = 0.66$) and variance (slope = 1.0). Model 16% less than observations

Simulate $\text{PM}_{2.5}$ with the 3D Model GEOS-Chem

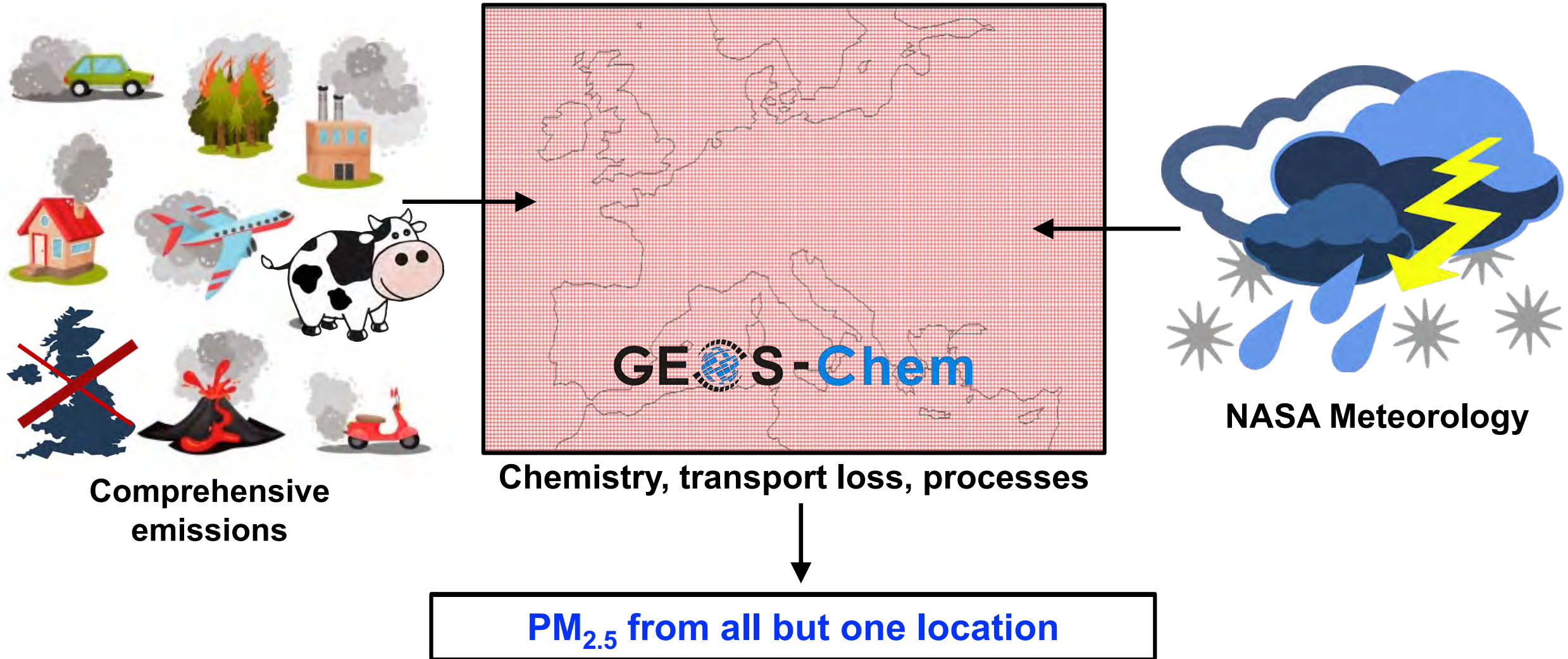
3D Atmospheric Chemistry Transport Model



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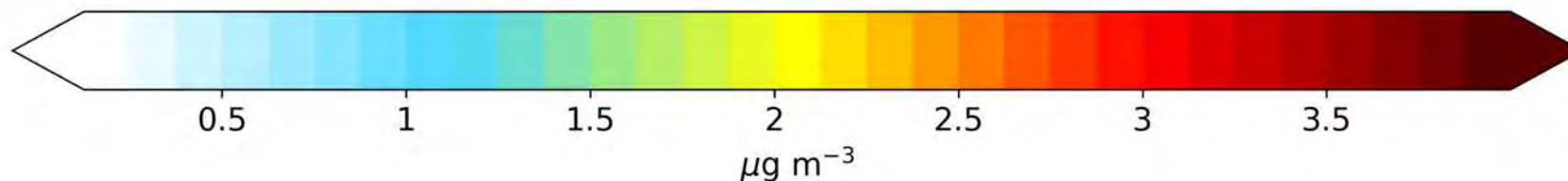
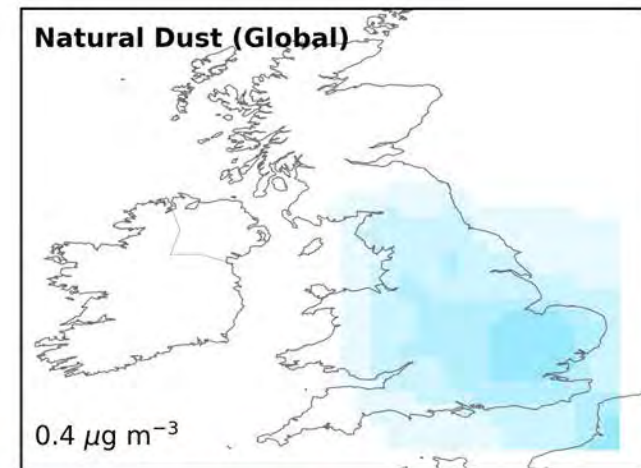
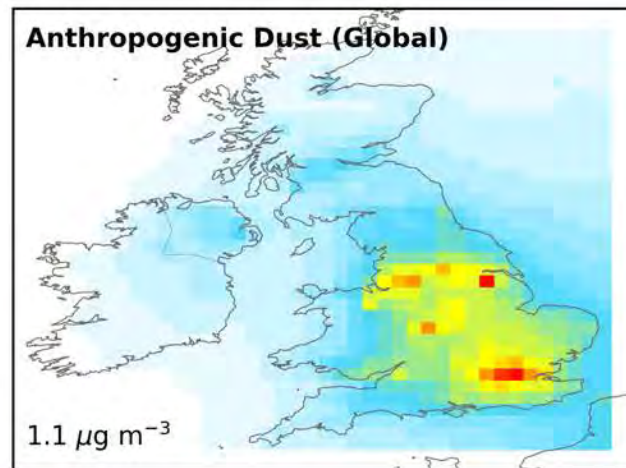
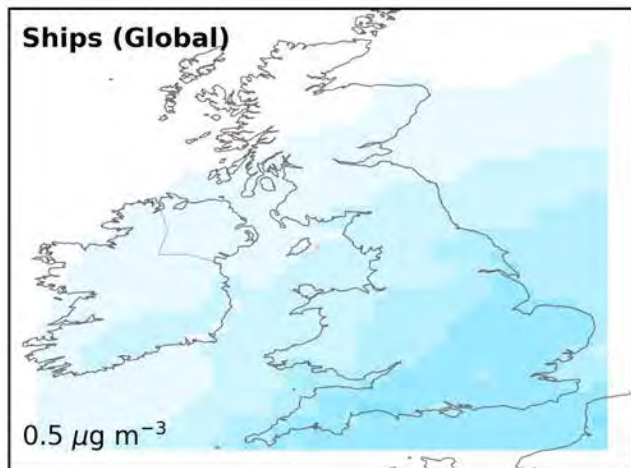
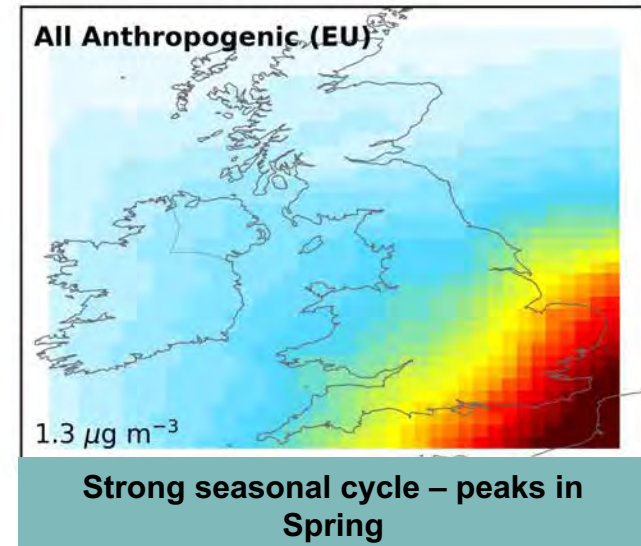
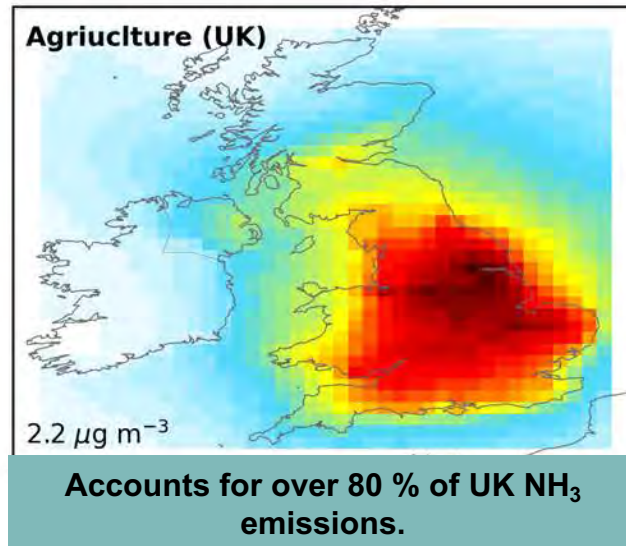
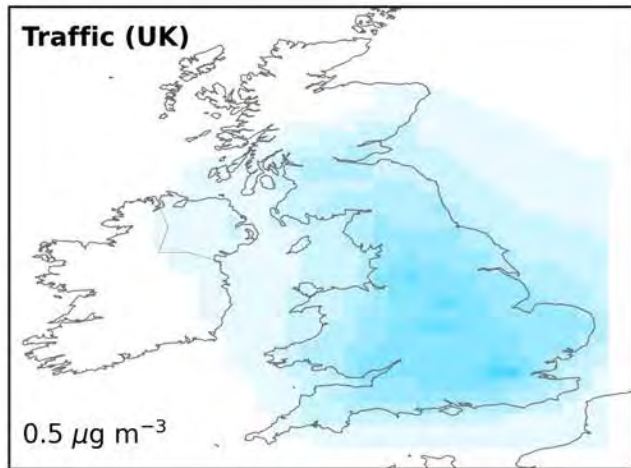
Simulate $\text{PM}_{2.5}$ with the 3D Model GEOS-Chem

3D Atmospheric Chemistry Transport Model



GEOS-Chem manual: <http://acmg.seas.harvard.edu/geos/>

Contribution of Sources to UK PM_{2.5}



Research Questions and Methodology Overview

Q1) What sectors are the biggest contributors to $PM_{2.5}$?

Q2) To what extent is $PM_{2.5}$ controlled by local emissions, versus transboundary emissions?



Leicester

London

Method #1 – Atmospheric modelling (UK-wide)

Eloise A Marais
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Method #2 – Low cost sensors (Leicester)

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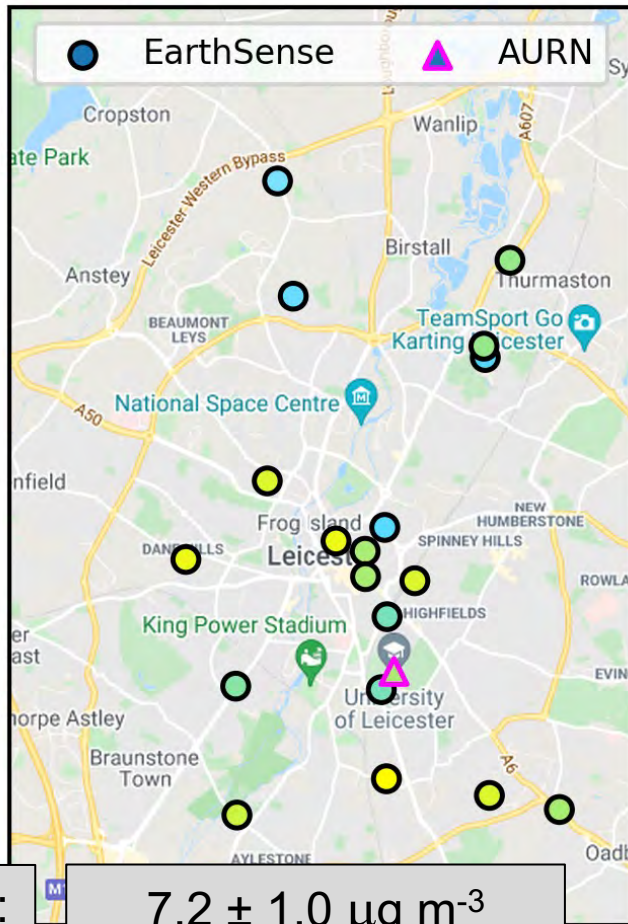
Corroborating Evidence from Low-Cost Sensors

Low-cost network of Zephyr sensors distributed throughout Leicester since November 2020

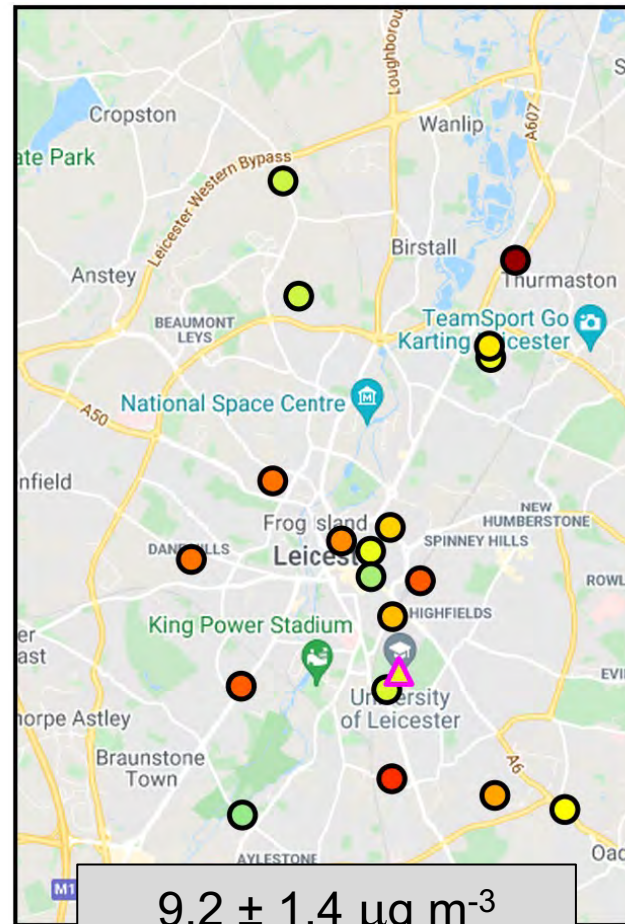


Corroborating Evidence from Low-Cost Sensors

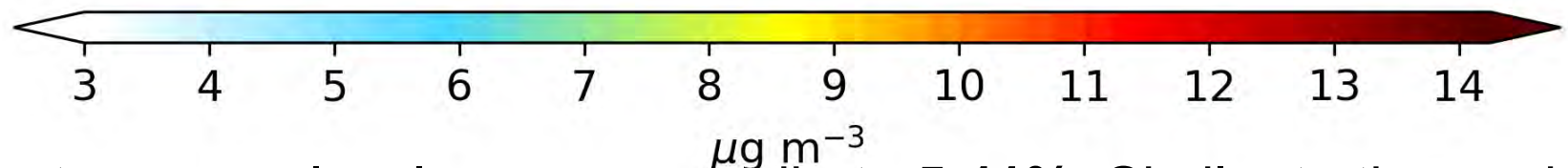
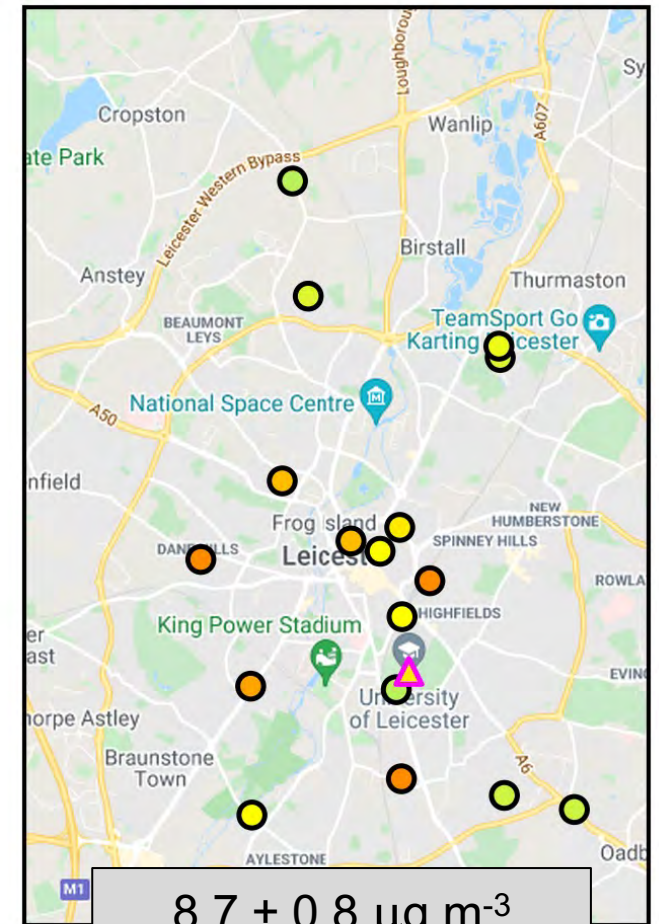
December 2020



January 2021



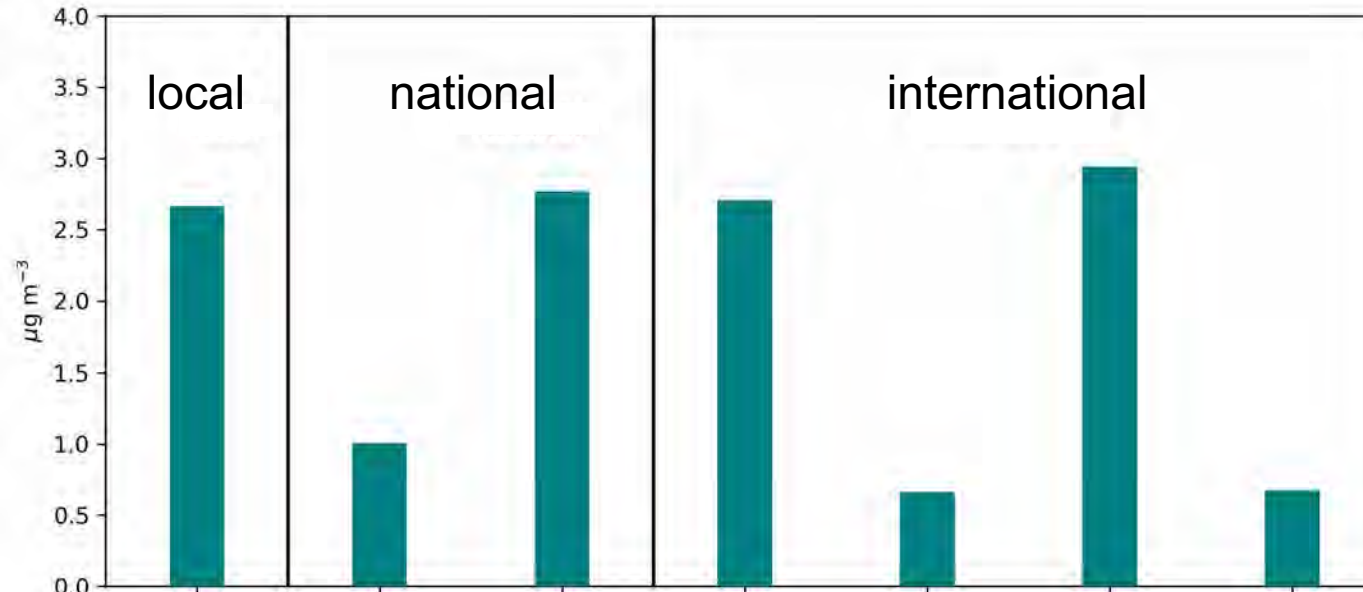
February 2021



According to low-cost sensors, local sources contribute **5-11%**. Similar to the model (**3-5%**)

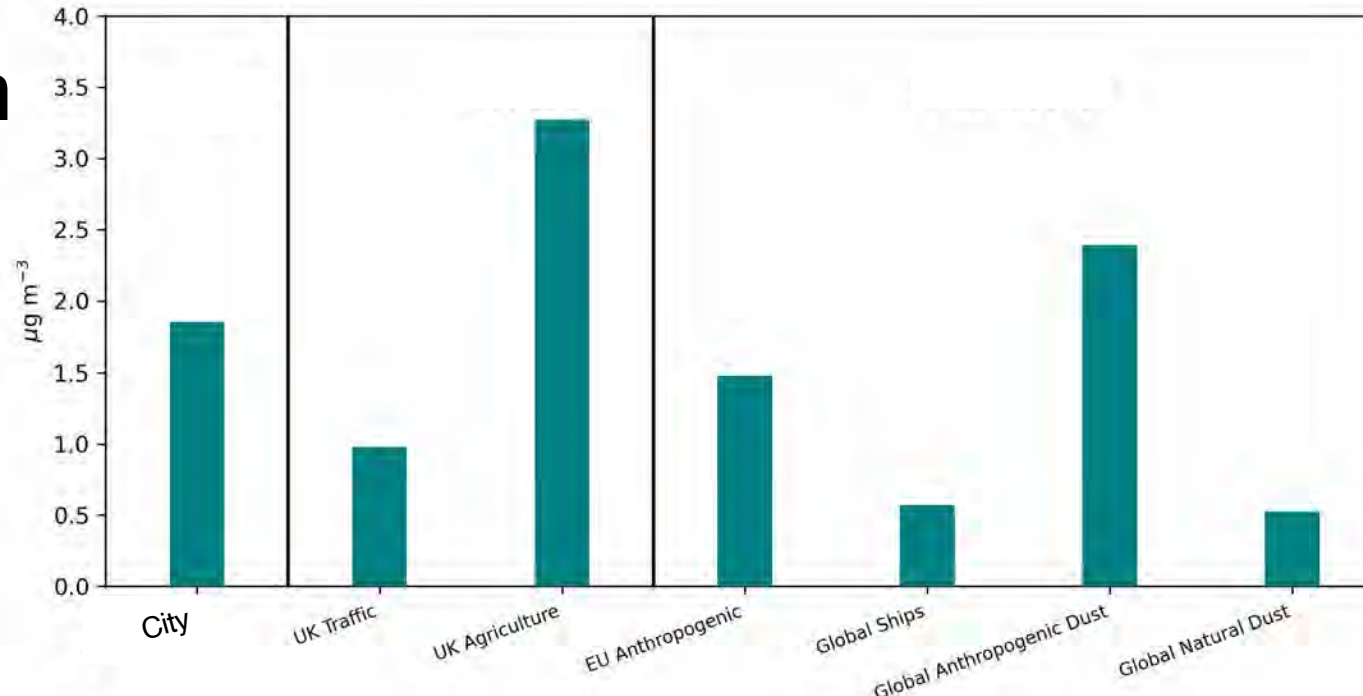
Results for Large Cities like London and Birmingham

London



London: 1,600 km²
Birmingham: 270 km²
Leicester: 70 km²

Birmingham



Broad applicability to other cities

Only in London is local PM_{2.5} similar to agriculture

Regulatory Framework for Air Pollution in the UK

International Bodies

Gothenburg
Protocol



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Leicester
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Setting of National Total Emission Ceilings

UK's emission reduction commitments...

- SO_2 = 59 %
- NO_x = 55 %
- NH_3 = 5 %

Monitoring Compliance with Standards

Designation of Local Air Quality Management Areas (LAQMAs)

- Develop and enforce air quality plan
- Often targets fossil fuel combustion

Conclusions and Acknowledgements

**Thanks for
listening!**

- Unregulated agriculture dominates PM_{2.5} year-round
- Mainland Europe makes large seasonal contribution to PM_{2.5} in November to April.
- Policies targeting local sources only effective for cities as large as London
- Results reinforce the need for continued and strengthened international agreements and measures to control ammonia emissions from agriculture
- Anthropogenic dust is a large source of uncertainty due to challenges representing emissions and evaluating the model

Support provided by Leicester City Council from a Defra-funded Air Quality Grant

