

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



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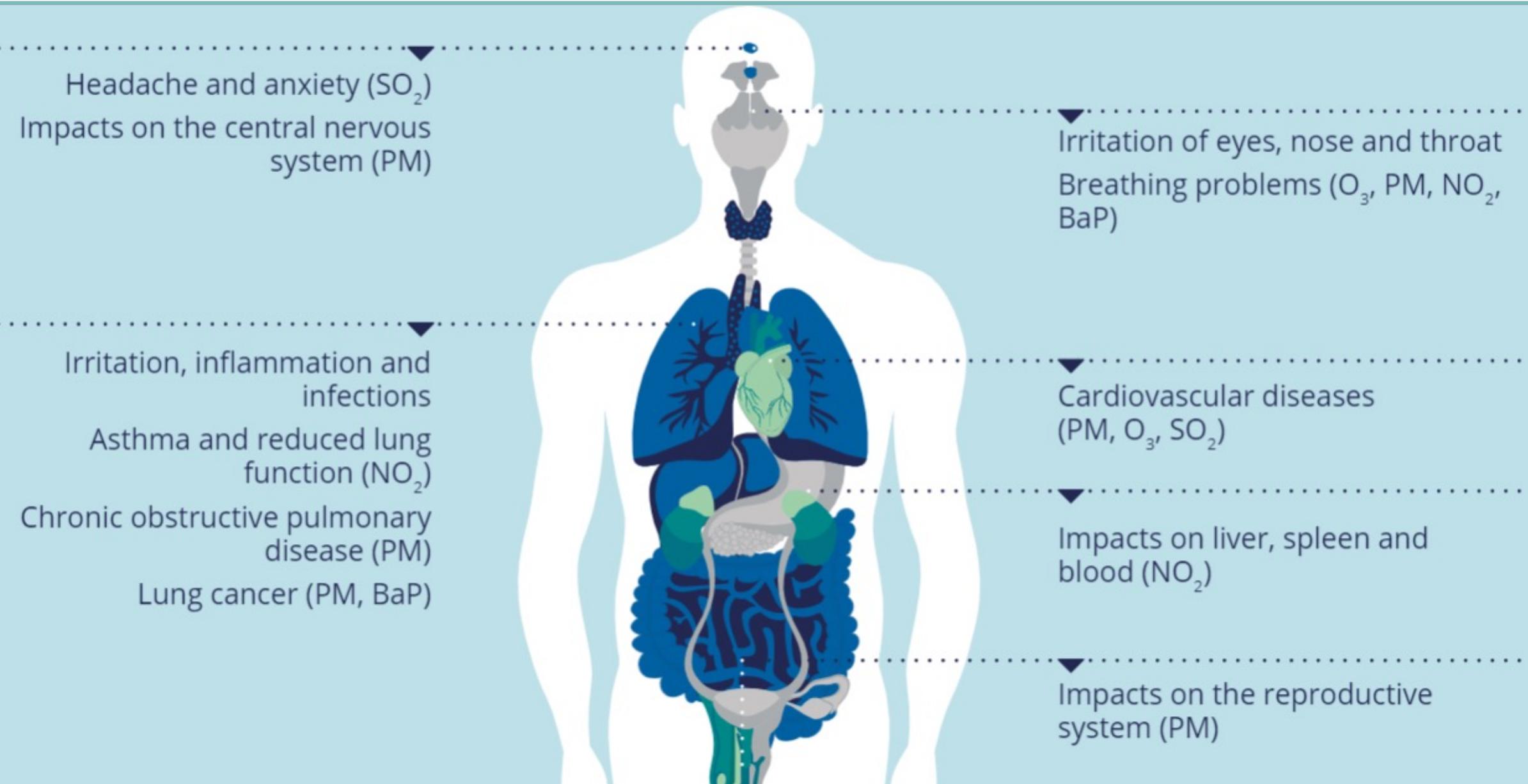
Roland Leigh
Jordan White

Ella Adoo-Kissi-Debrah



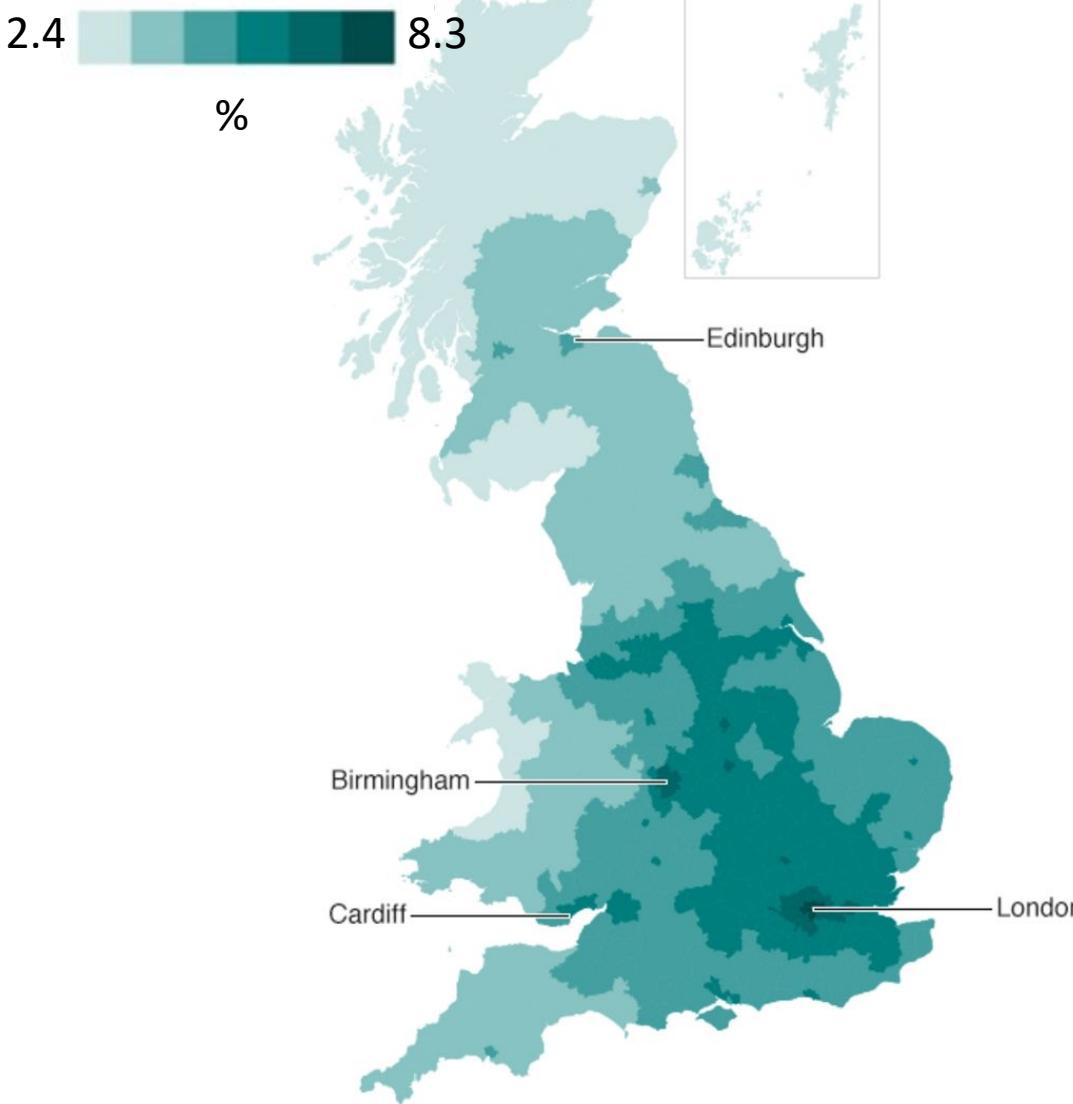
Source – Ella Roberts Foundation (<http://ellaroberta.org/about-ella/>)

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



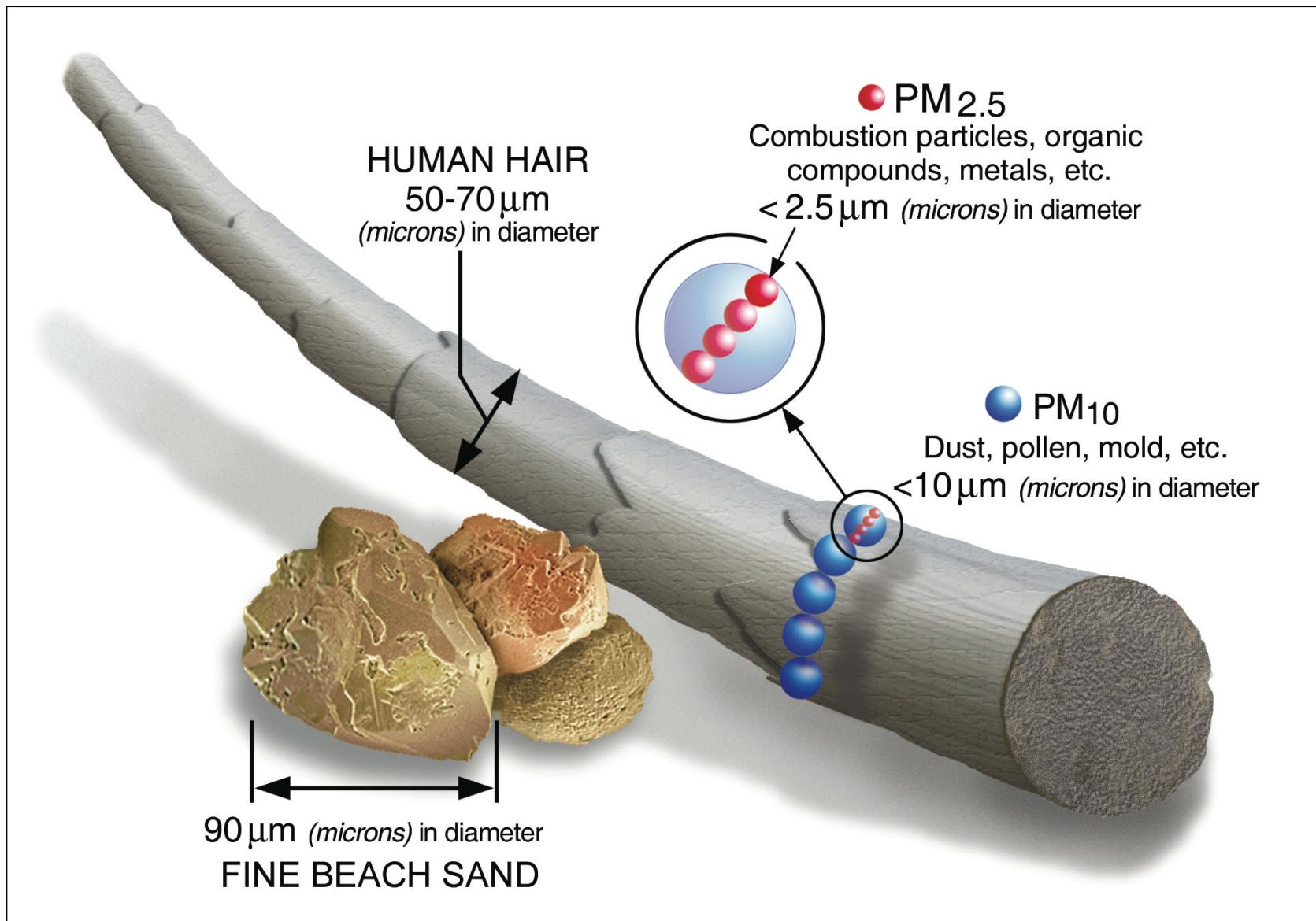
Highest mortality rates in polluted and populated regions (e.g. London)

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



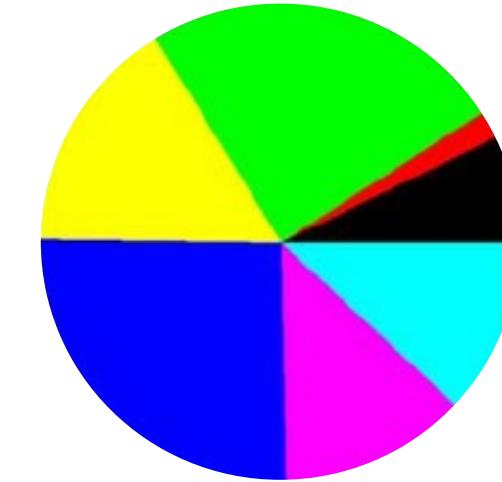
Source – US Environmental Protection Agency (EPA)

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	secondary
Nitrate	
Ammonium	
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



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



At all times

ZONE

ULEZ

Ultra low
emission

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



Sources of UK PM_{2.5}

Traffic



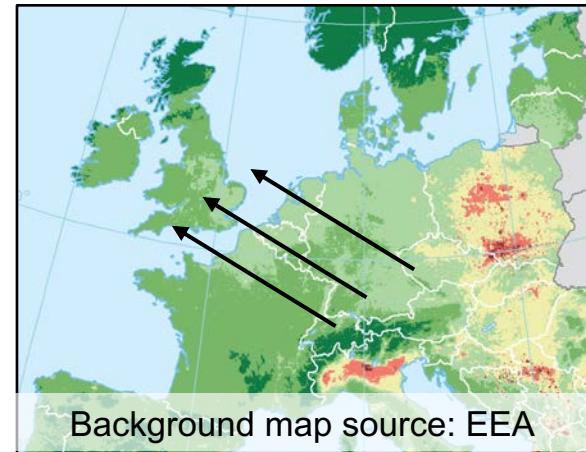
Agriculture



City



Regional



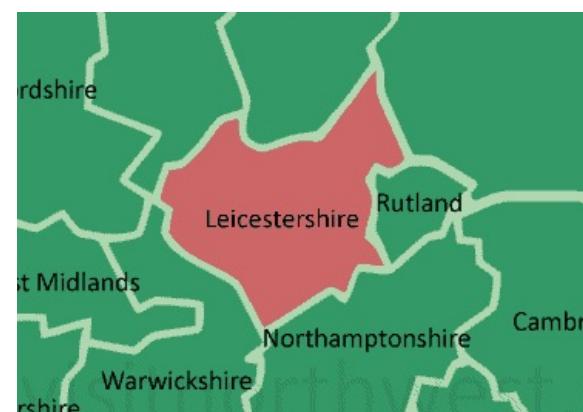
Shipping



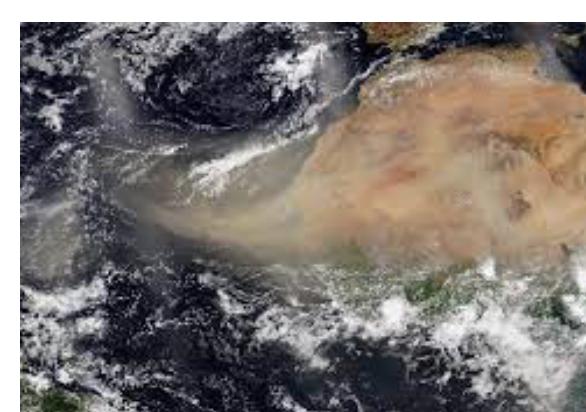
Construction



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**

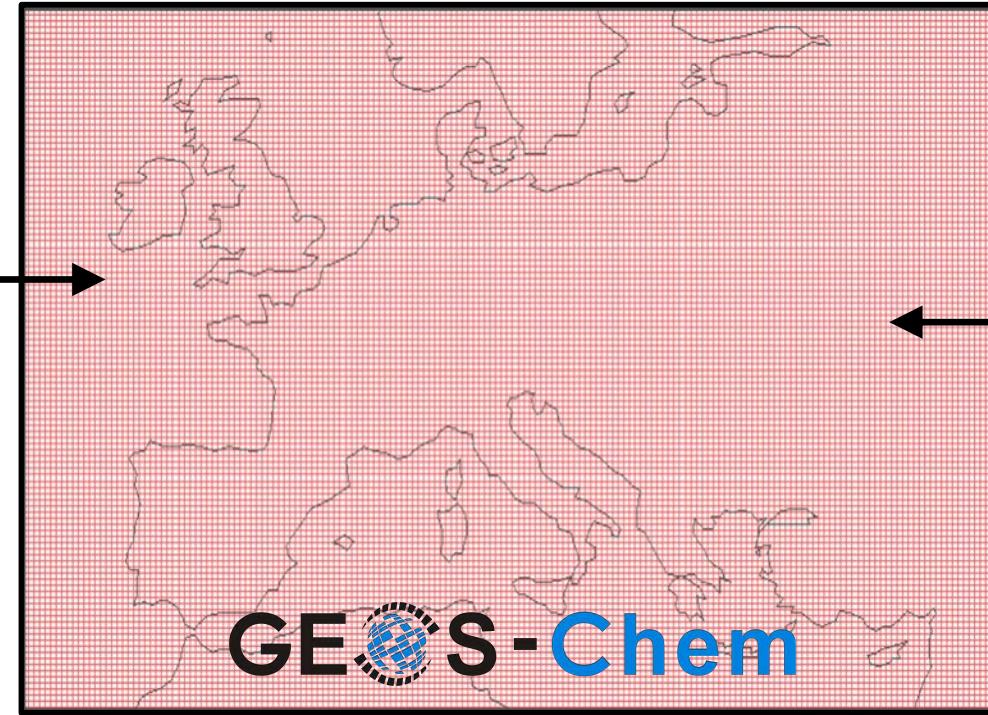


Simulate PM_{2.5} with the 3D Model GEOS-Chem

3D Atmospheric Chemistry Transport
Model



Comprehensive
emissions



Chemistry, transport, and loss
processes



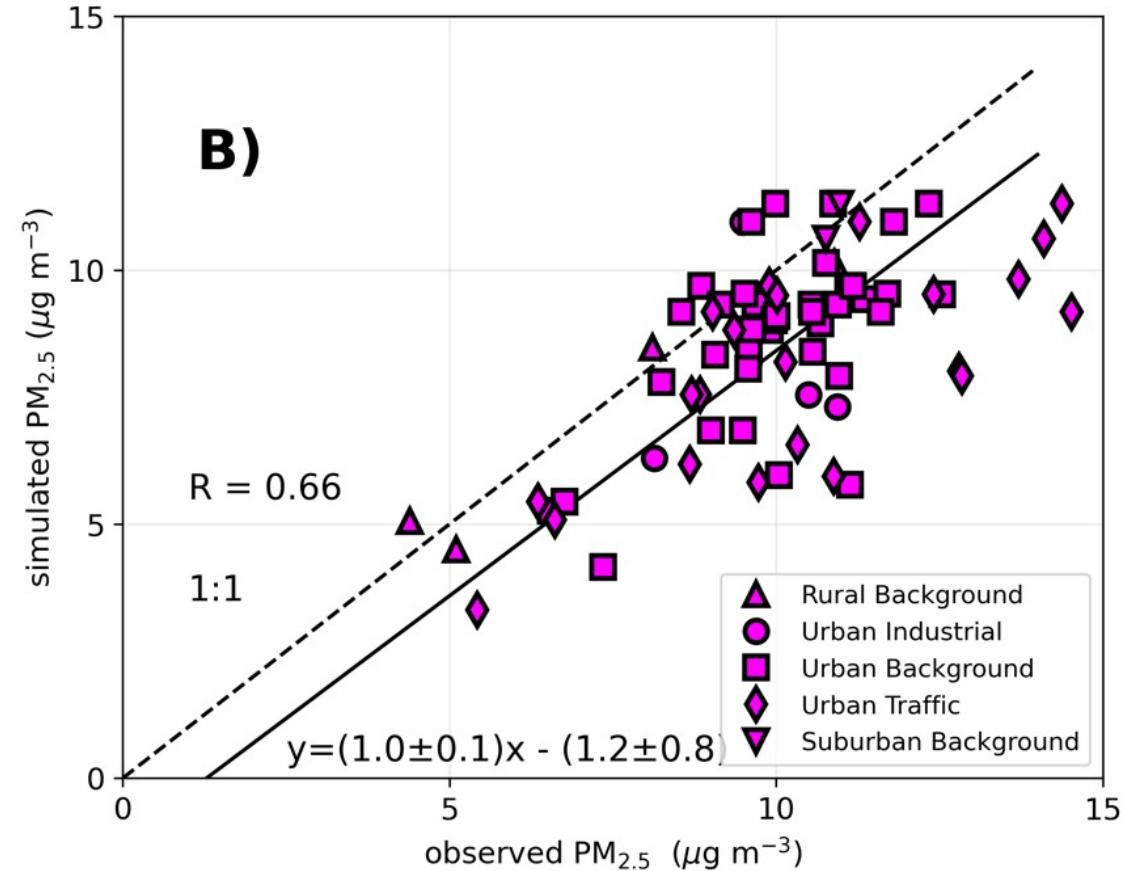
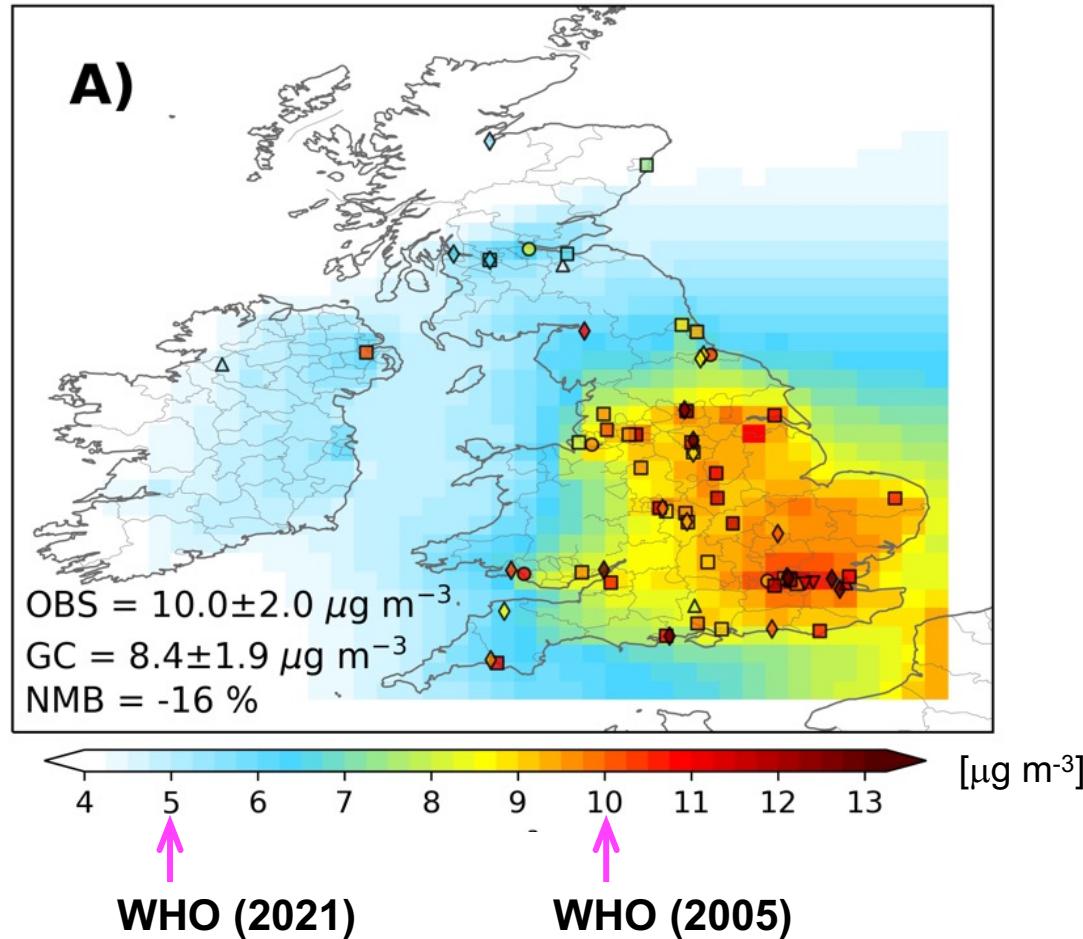
NASA Meteorology

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



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

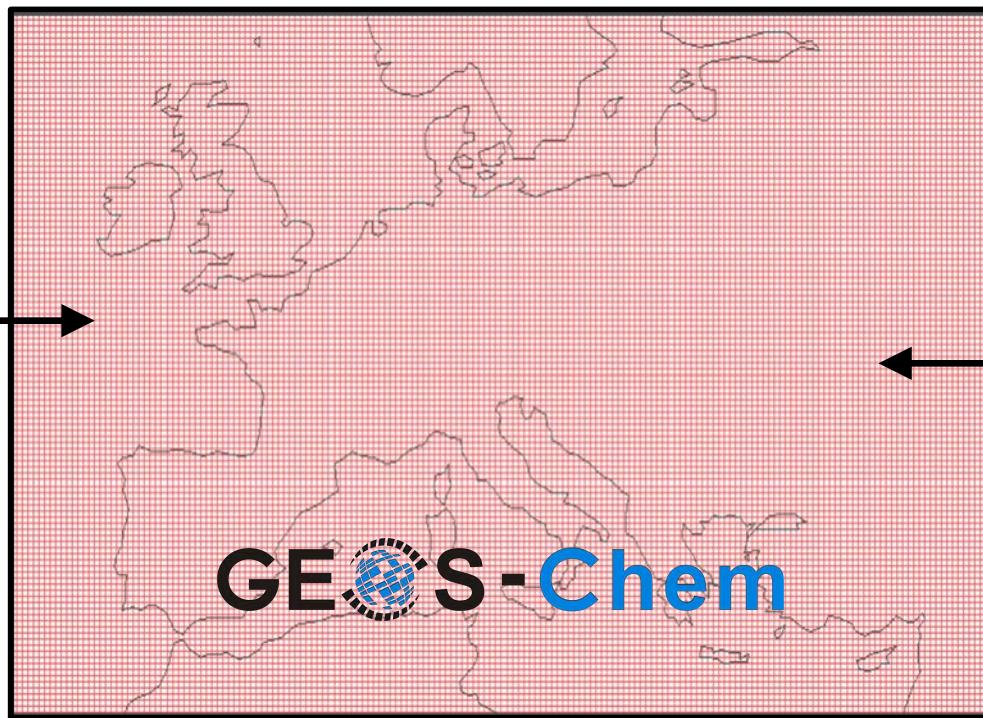
74% of UK exceeds updated WHO guideline

Simulate PM_{2.5} with the 3D Model GEOS-Chem

3D Atmospheric Chemistry Transport Model



Comprehensive
emissions



Chemistry, transport loss, processes

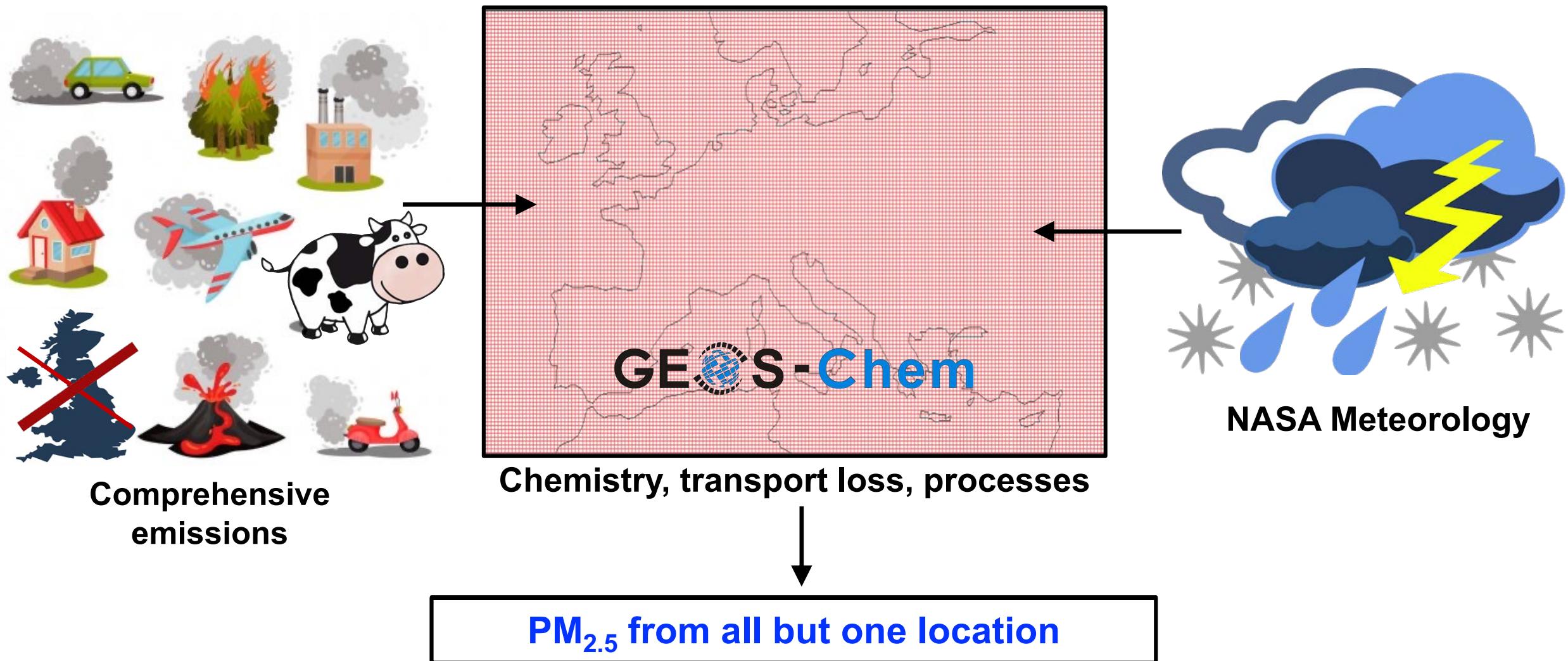


NASA Meteorology

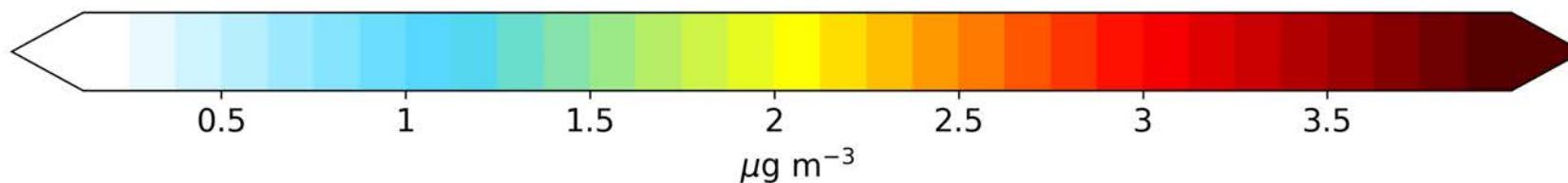
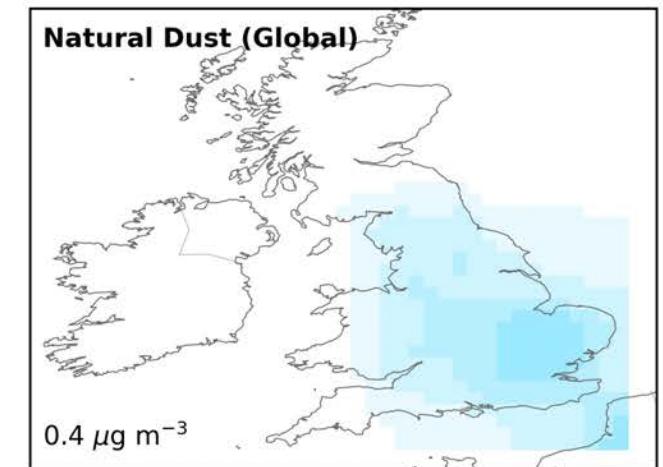
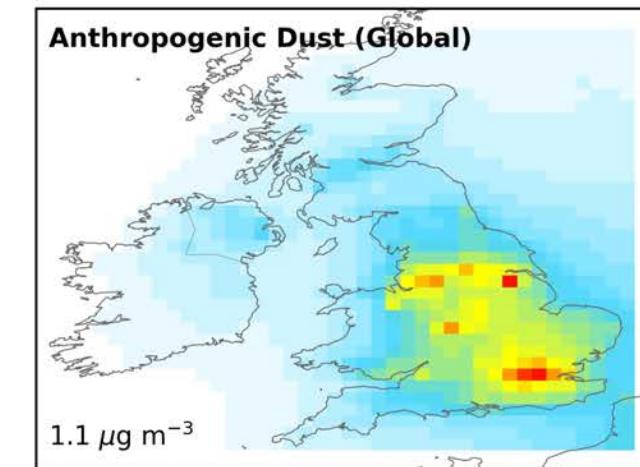
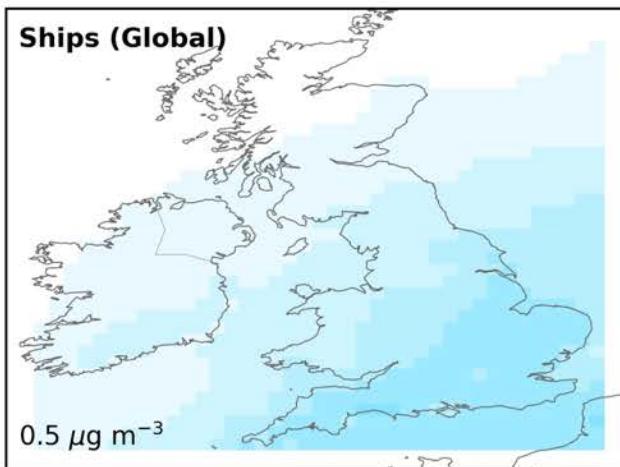
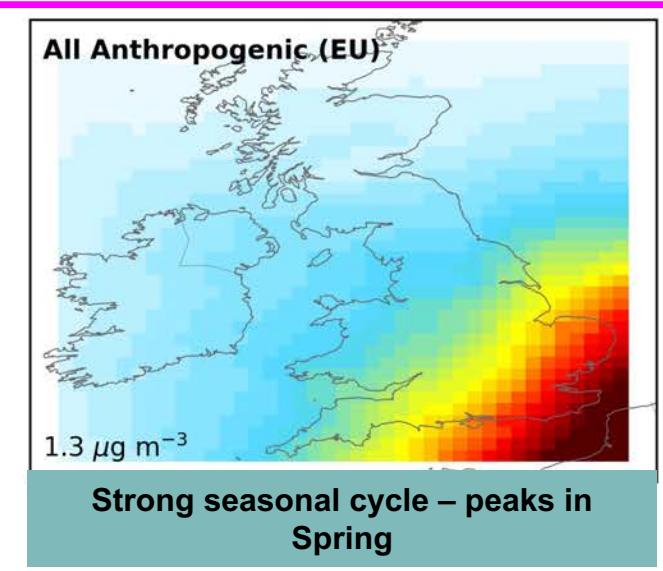
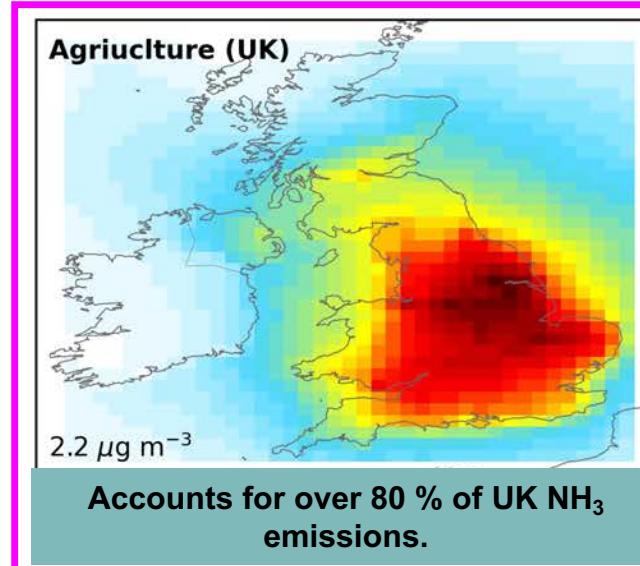
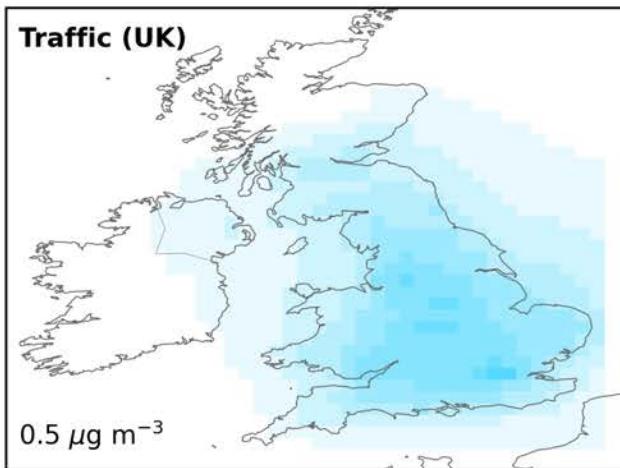
PM_{2.5} from all but one source

Simulate PM_{2.5} with the 3D Model GEOS-Chem

3D Atmospheric Chemistry Transport Model



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
Jamie M Kelly**



Method #2 – Low cost sensors (Leicester)

**Roland Leigh
Jordan White**



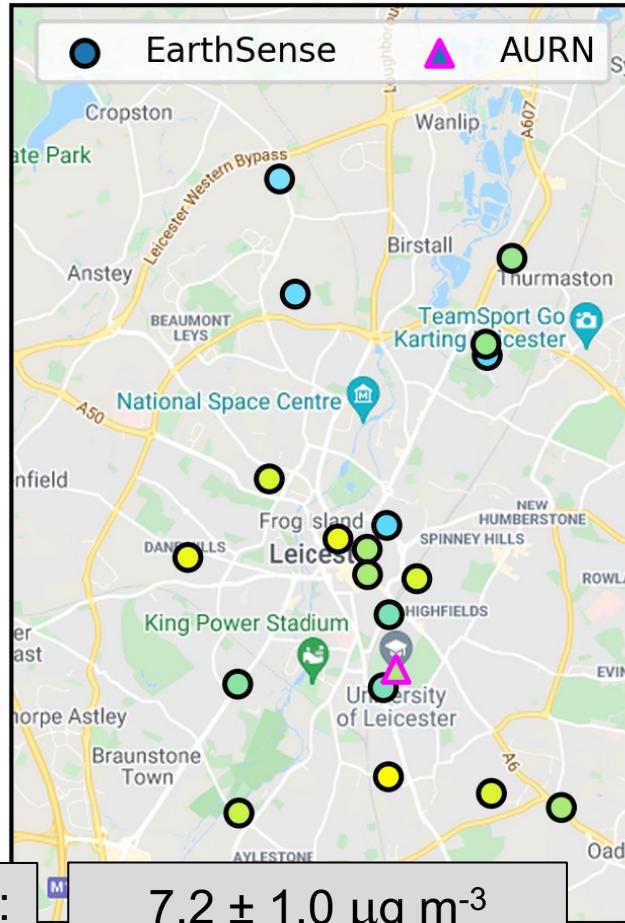
Corroborating Evidence from Low-Cost Sensors

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

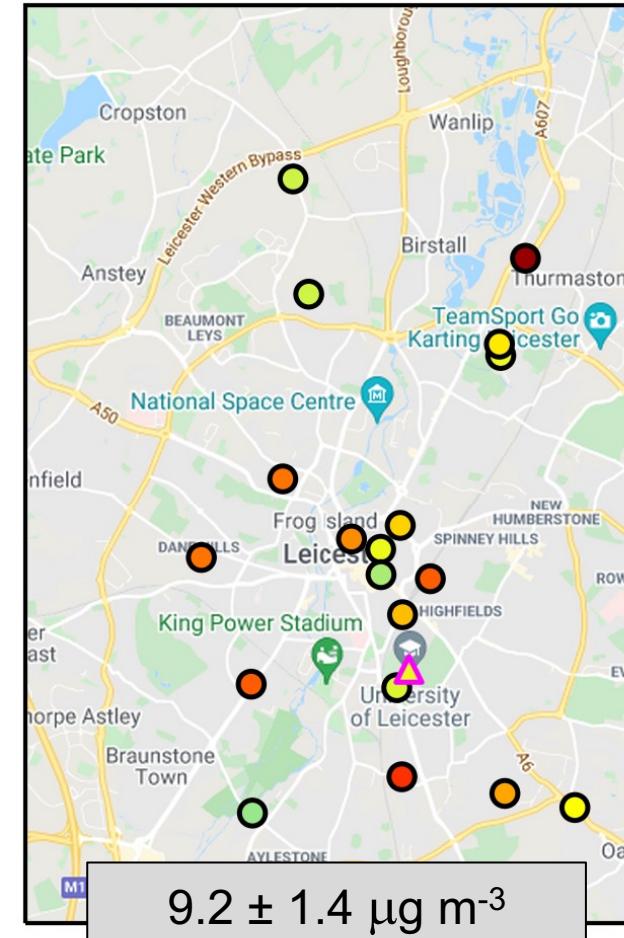


Corroborating Evidence from Low-Cost Sensors

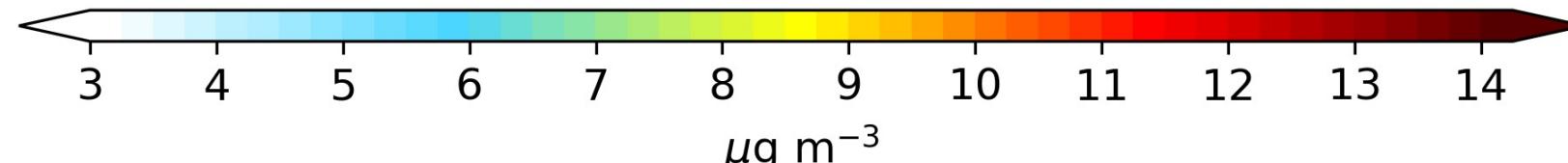
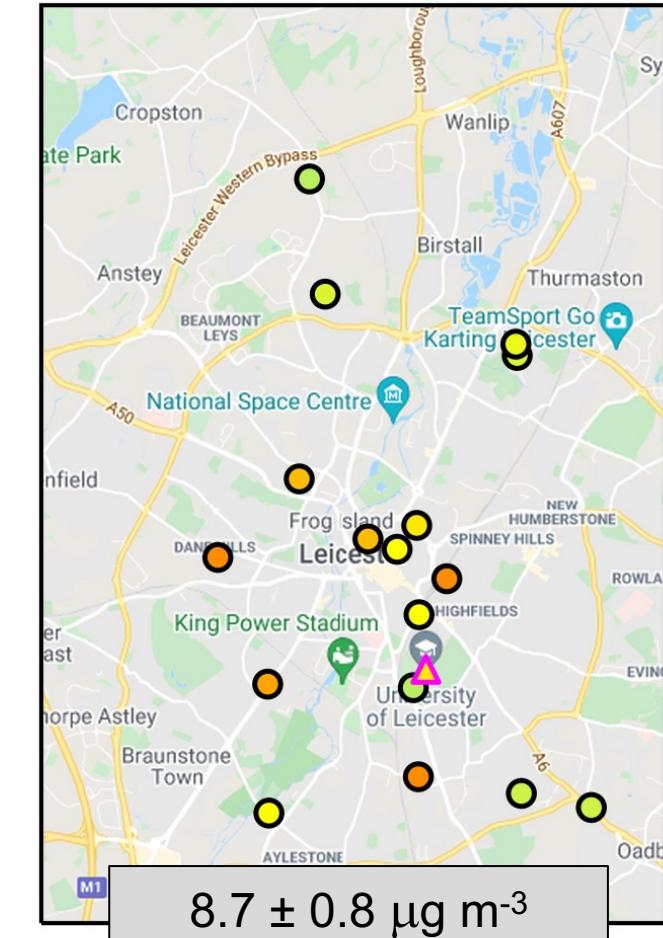
December 2020



January 2021



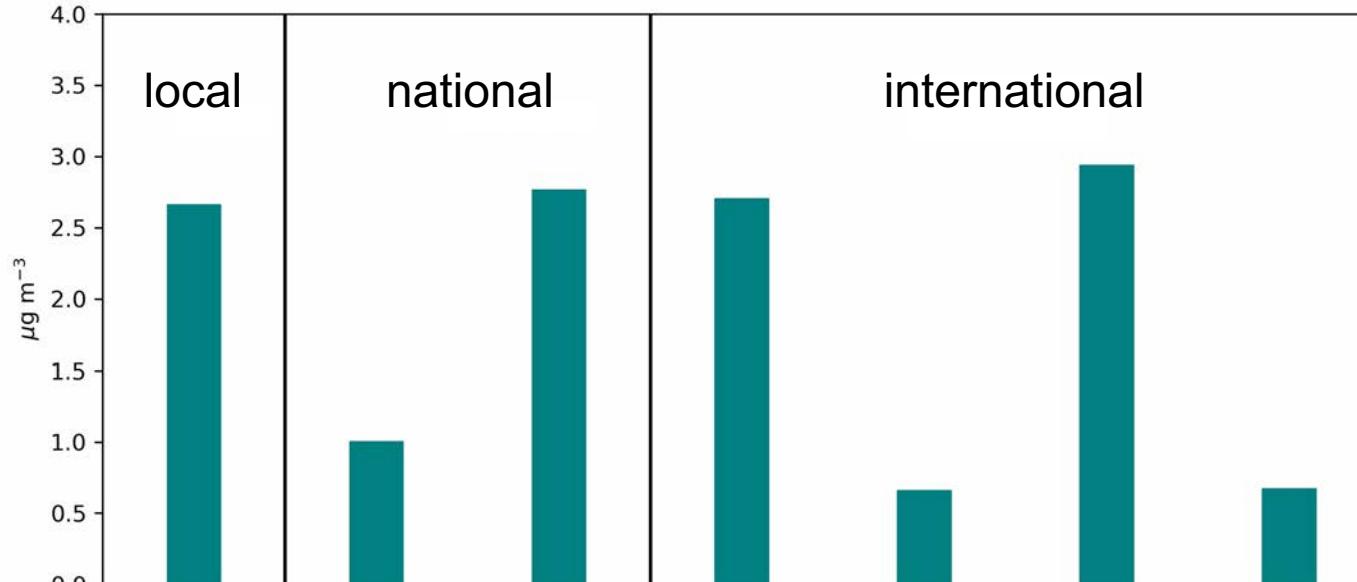
February 2021



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

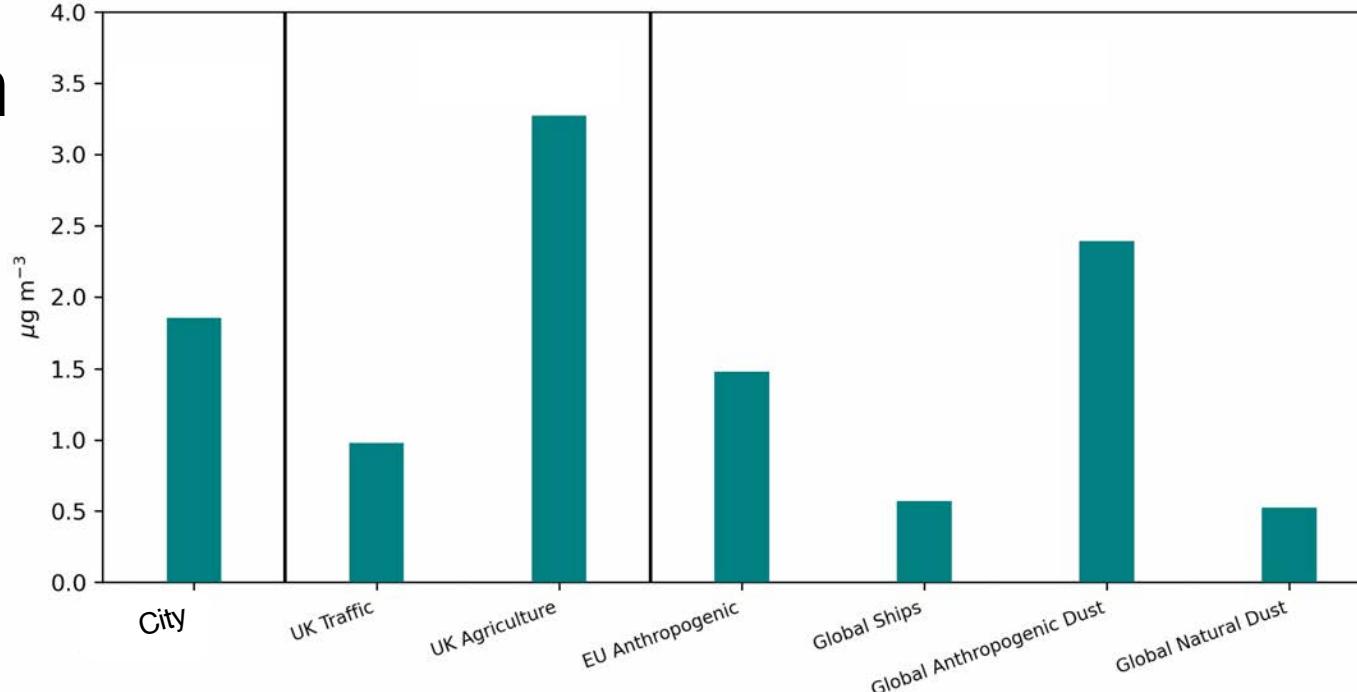
Results for Large Cities like London and Birmingham

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



National Government

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



Department
for Environment
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Setting of National Total Emission Ceilings

UK's emission reduction commitments...

- $\text{SO}_2 = 59\%$
- $\text{NO}_x = 55\%$
- $\text{NH}_3 = 5\%$

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

- 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

Thanks for
listening!

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



Leicester
City Council



Department
for Environment
Food & Rural Affairs