

# Sources and Challenges in Regulating Fine Particles (PM<sub>2.5</sub>) in UK Cities



**UCL**

**Eloise A Marais**  
**Jamie M Kelly**



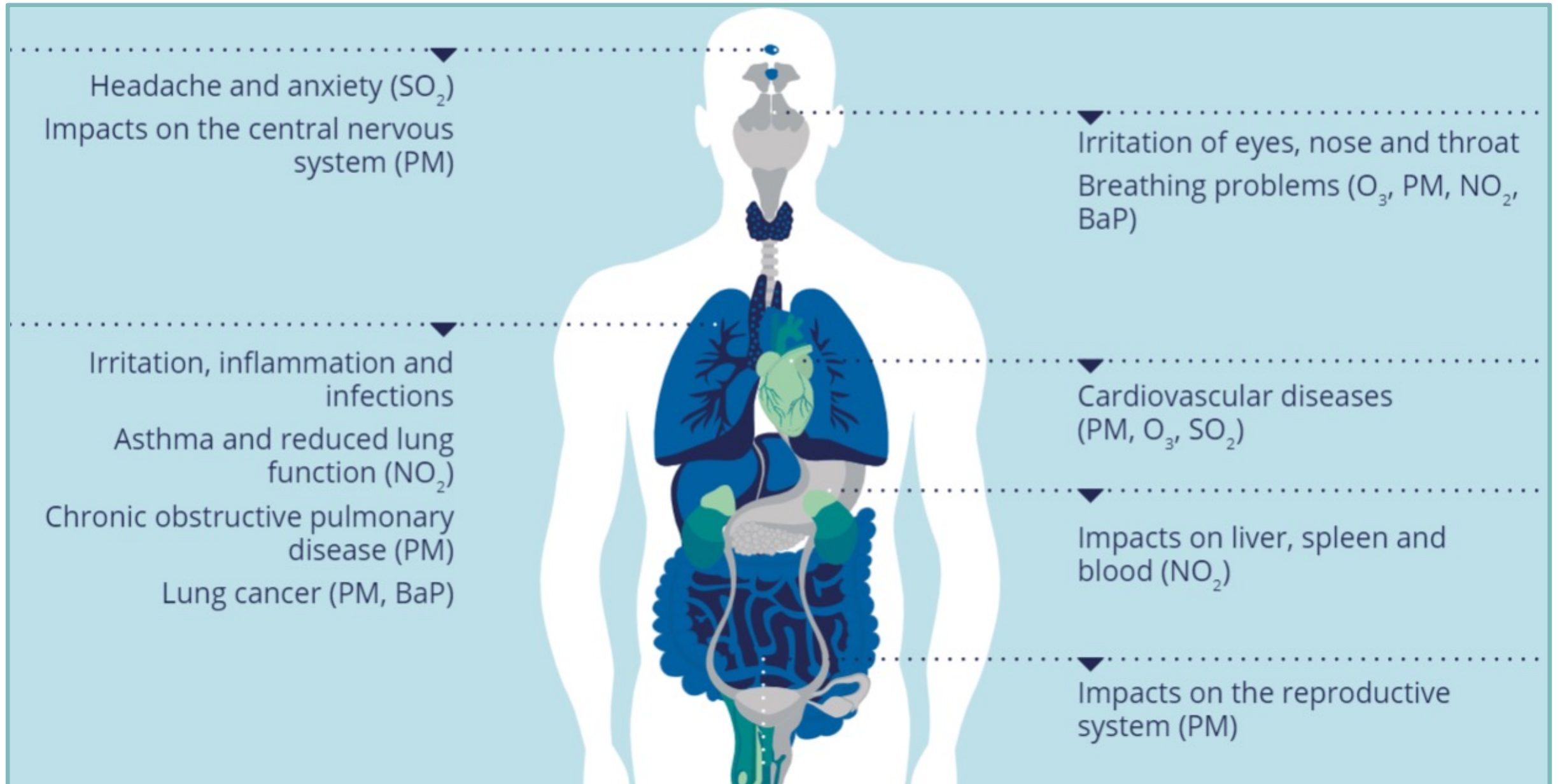
**Roland Leigh**  
**Jordan White**

## Ella Adoo-Kissi-Debrah



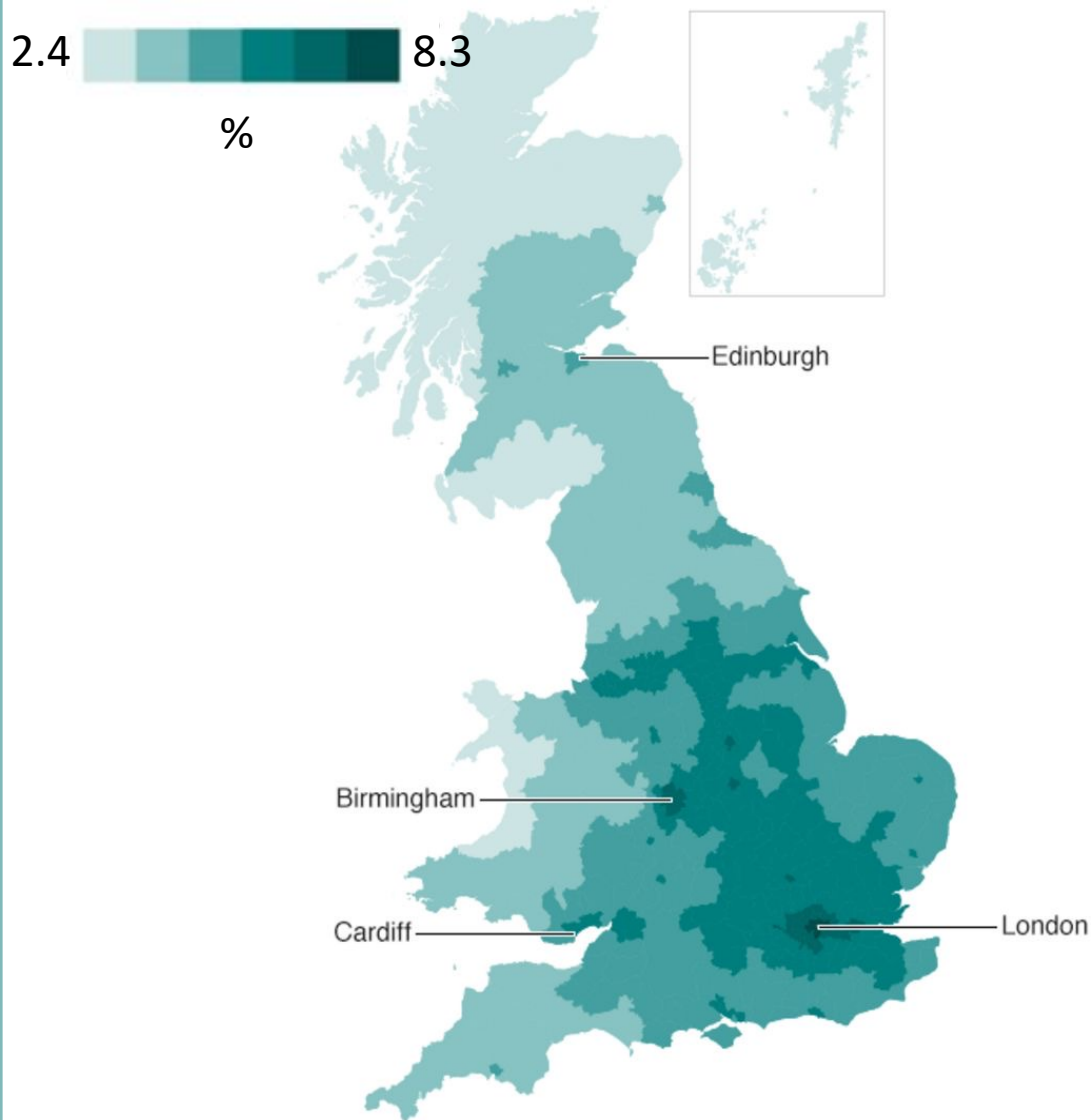
Source – Ella Roberts Foundation (<http://ellaroberta.org/about-ella/>)

# 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



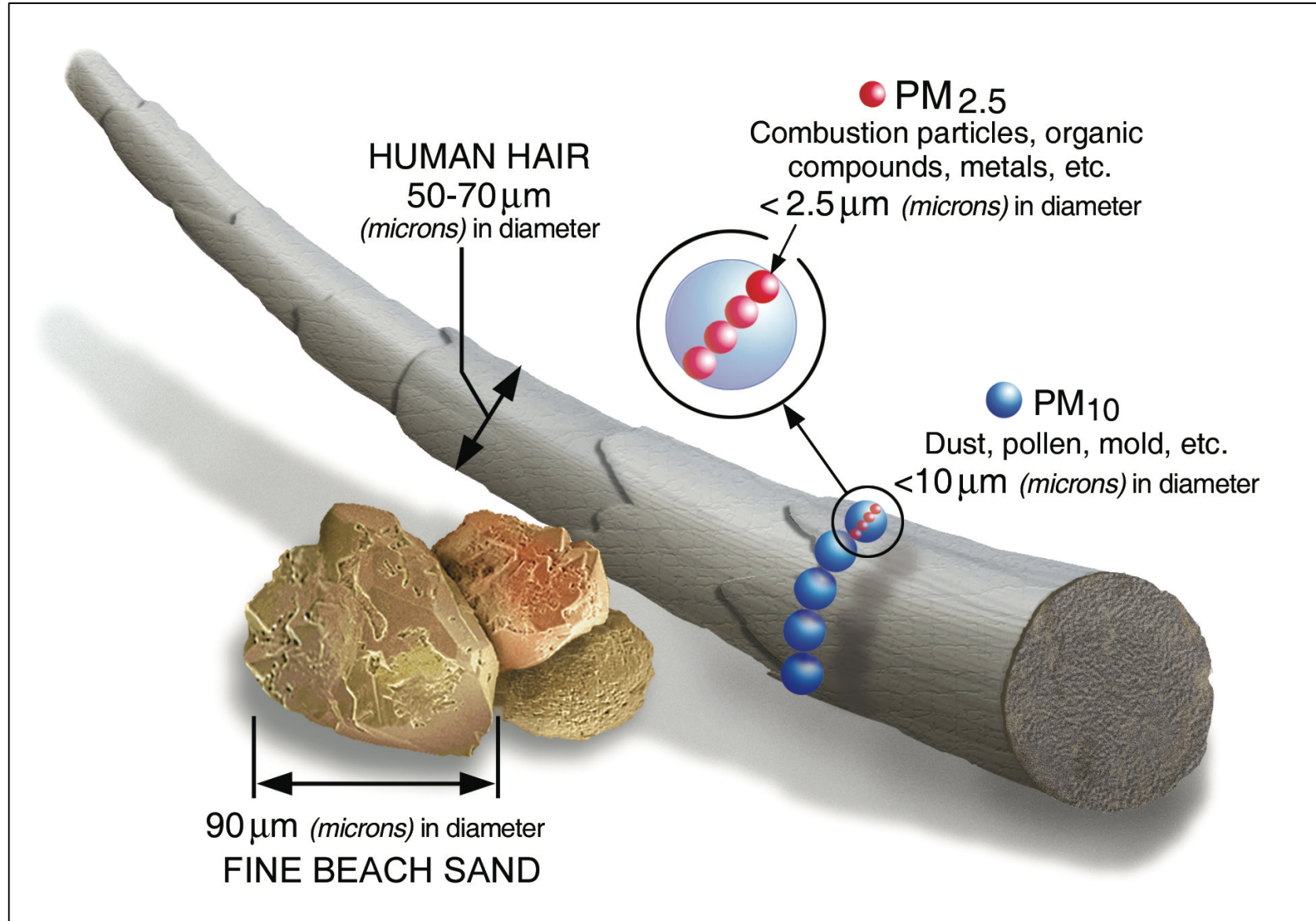
Highest mortality rates in polluted and populated regions (e.g. London)

Annual mortality rates...

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

Most important pollutant are Fine Particles (PM<sub>2.5</sub>)

# Fine Particles



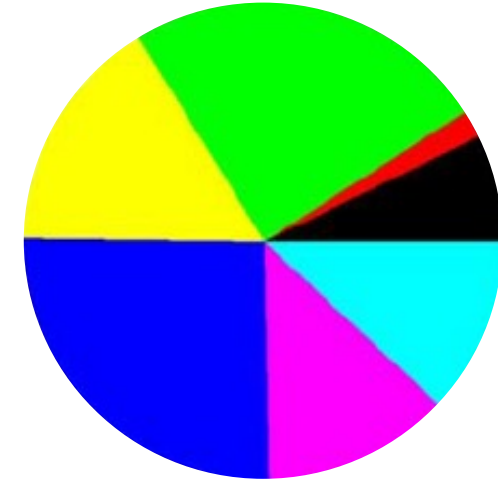
Source – US Environmental Protection Agency (EPA)

# Particles are a mix of components that persist for days

Direct emission  
of PM<sub>2.5</sub>  
(primary)

Emission of gas-phase  
precursors  
(secondary)

PM<sub>2.5</sub> includes a mix of components



Black carbon **primary**

Sulfate

Nitrate

Ammonium

**secondary**

Other inorganics

Organic aerosols **primary+secondary**

PM<sub>2.5</sub> 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](https://tfl.gov.uk/ulez)

# Sources of UK PM<sub>2.5</sub>

## Traffic



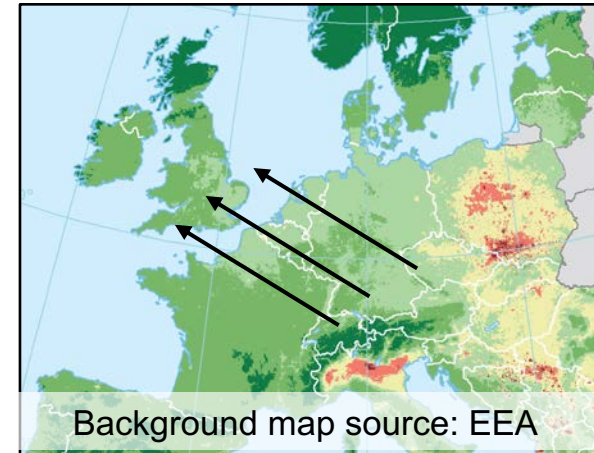
## Agriculture



## City



## Regional



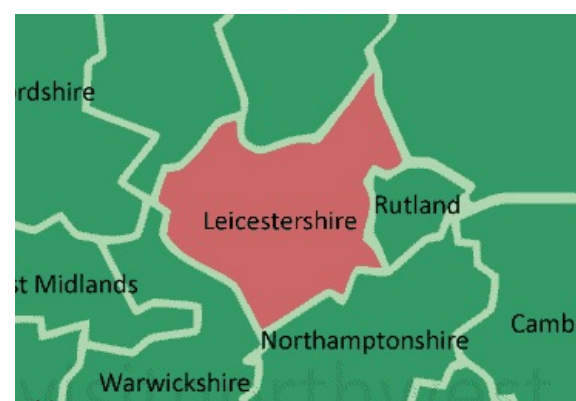
## Shipping



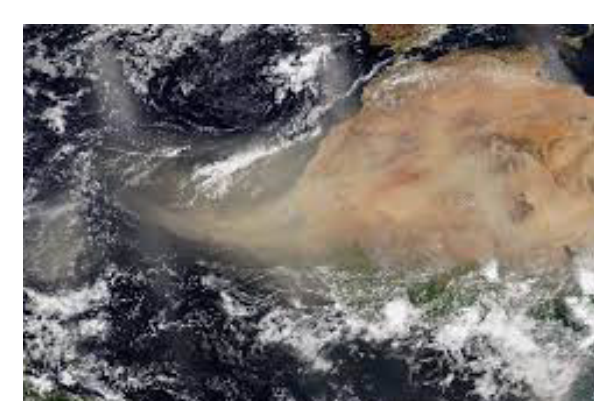
## Construction



## County

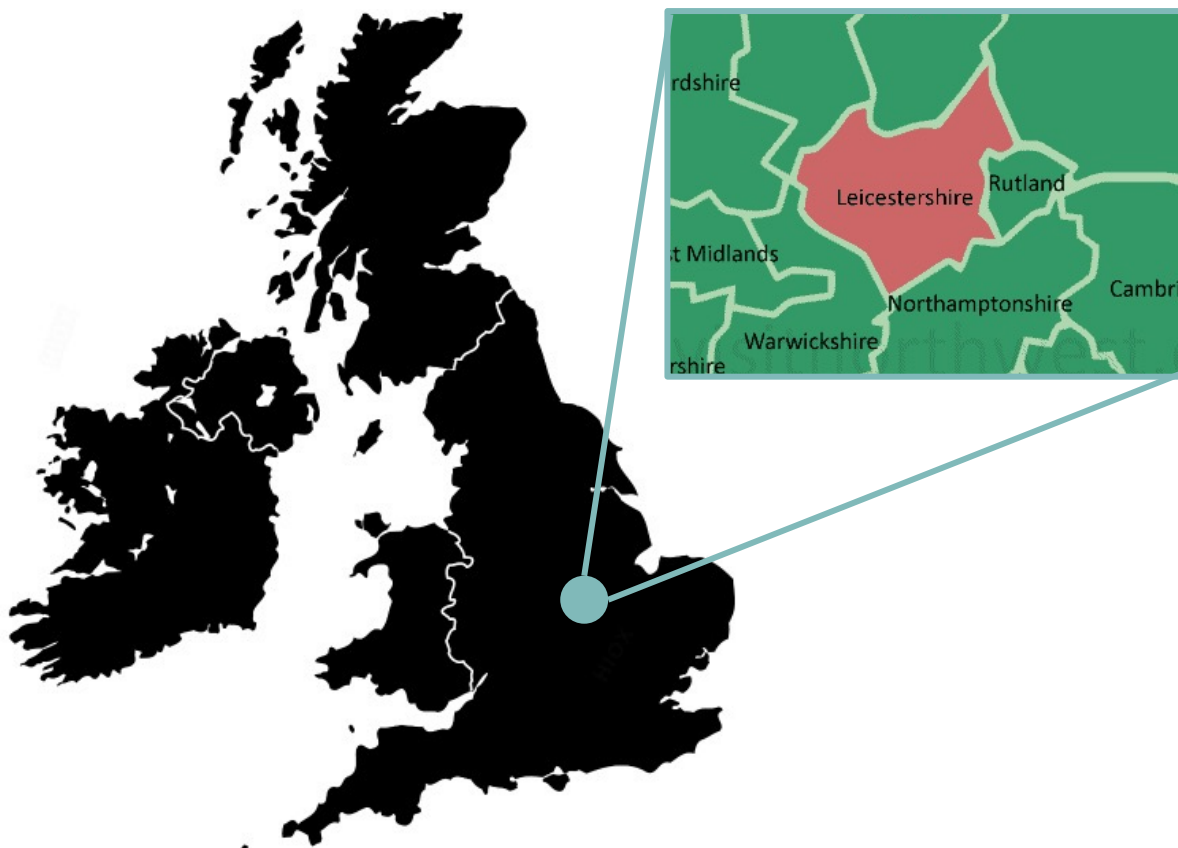


## Global



# Research Questions and Methodology Overview

RQ) What regions and sectors are the biggest contributors to PM<sub>2.5</sub>?



Method #1 – Atmospheric modelling (UK-wide)

**Eloise A Marais**  
**Jamie M Kelly**



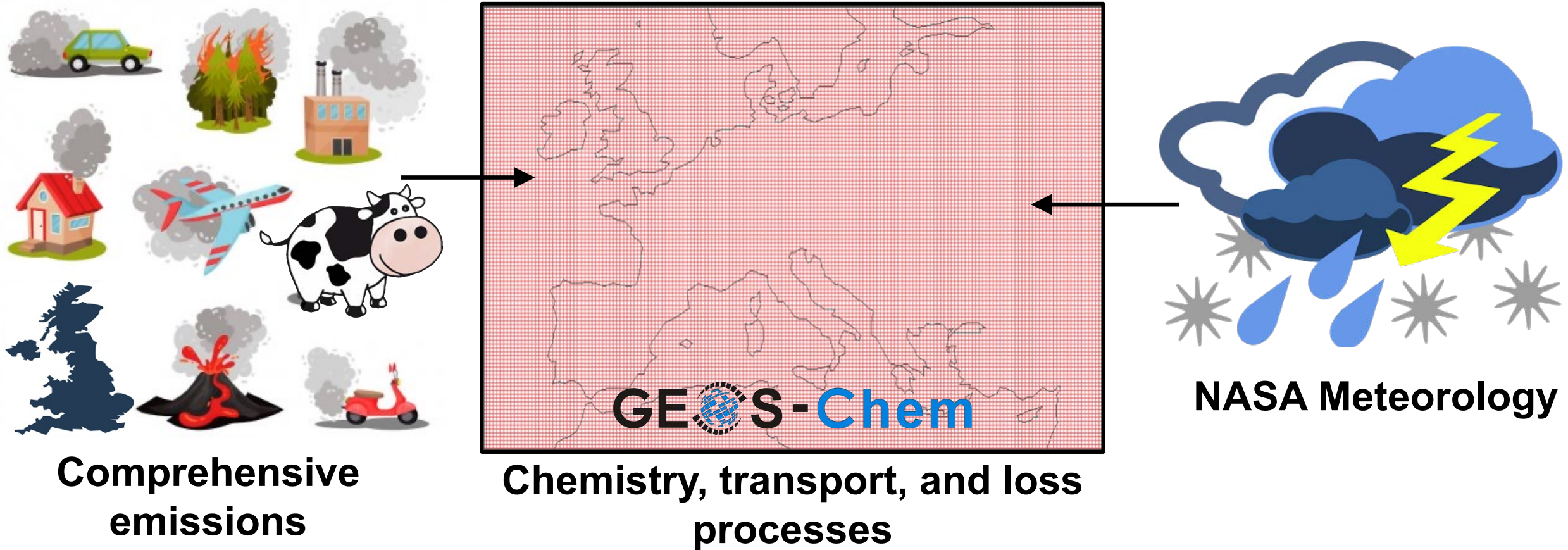
Method #2 – Low cost sensors (Leicester)

**Roland Leigh**  
**Jordan White**



# Simulate PM<sub>2.5</sub> with the 3D Model GEOS-Chem

3D Atmospheric Chemistry Transport  
Model

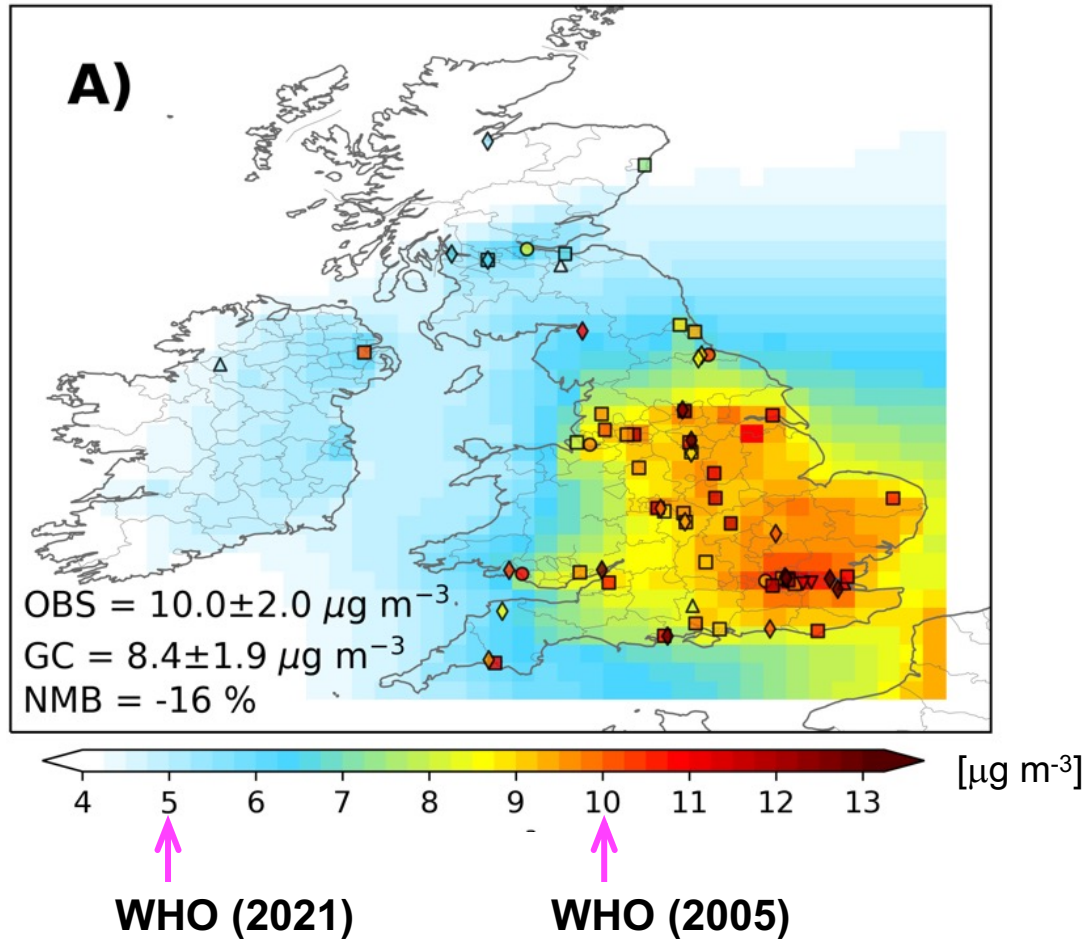


GEOS-Chem manual: <http://acmg.seas.harvard.edu/geos/>

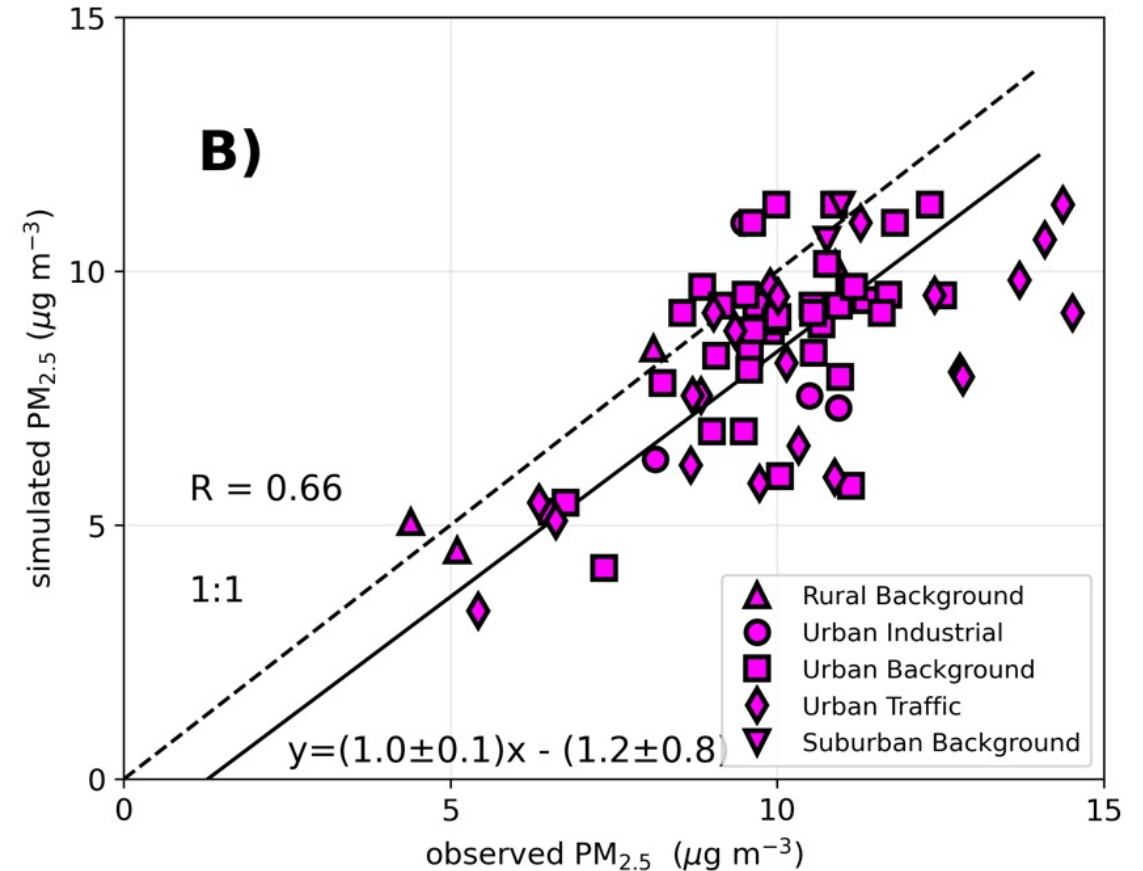
# Assess Validity of Model using Reference Monitors

Use total PM<sub>2.5</sub> observations from the Automatic Urban and Rural Network (AURN) to assess model

## Comparison of annual mean surface concentrations of PM<sub>2.5</sub> for 2019



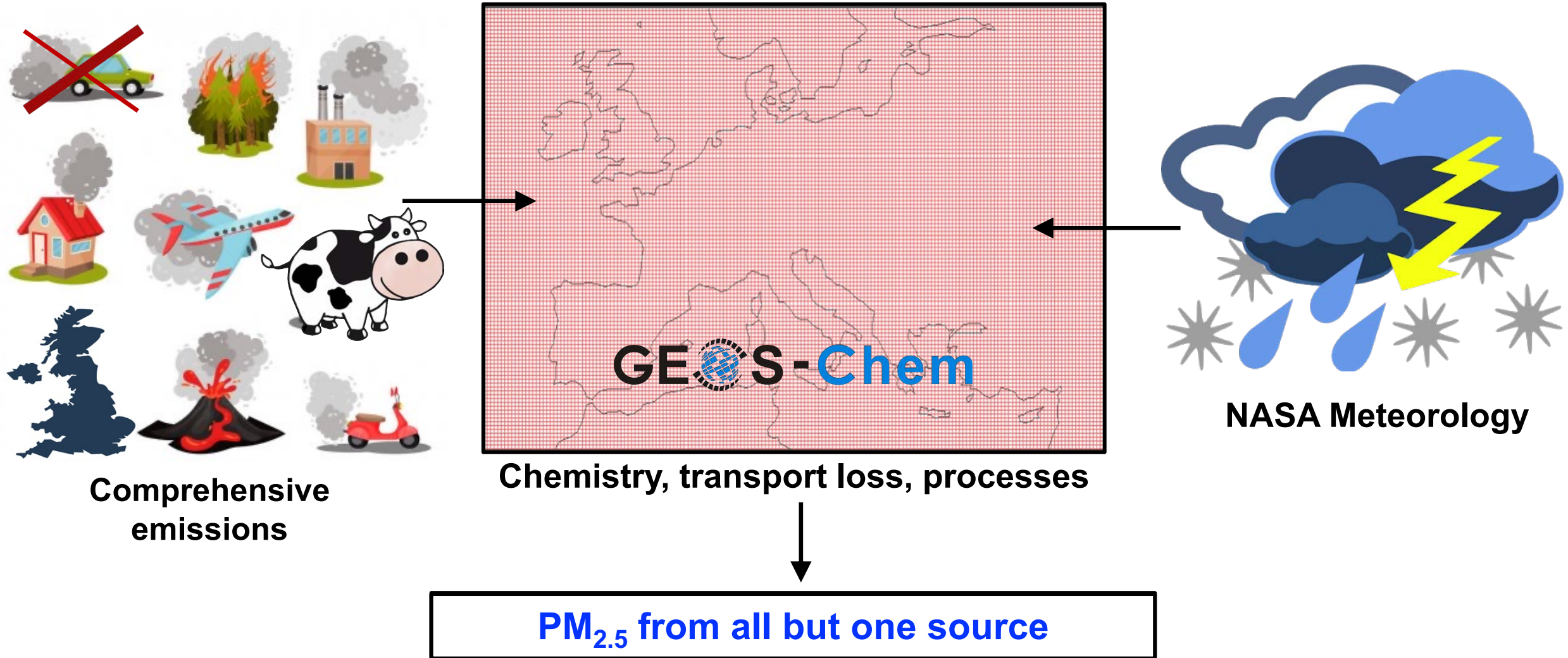
74% of UK exceeds updated WHO guideline



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

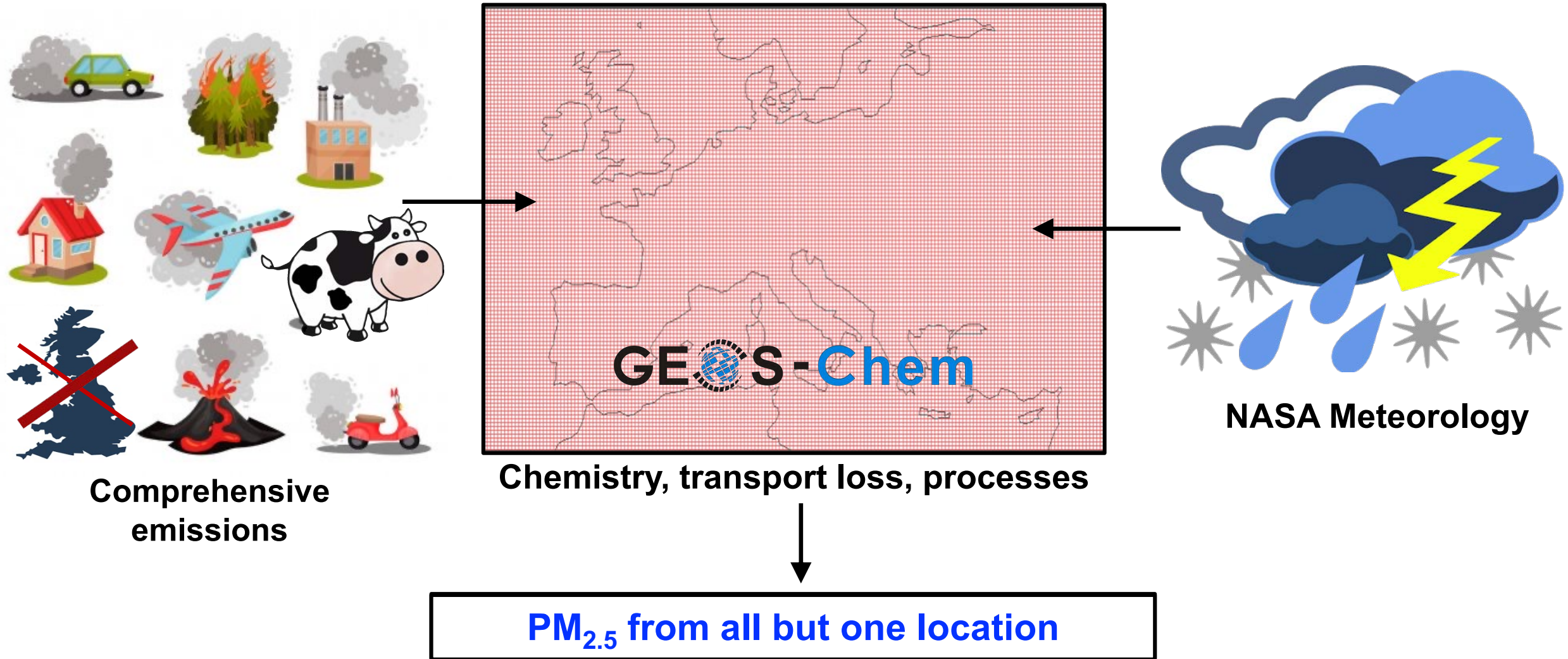
3D Atmospheric Chemistry Transport Model



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

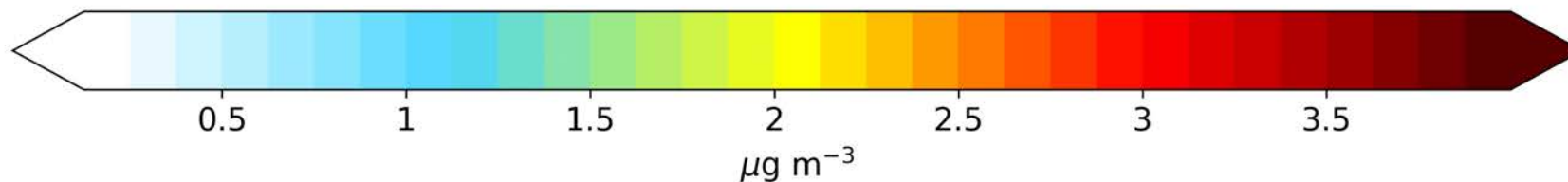
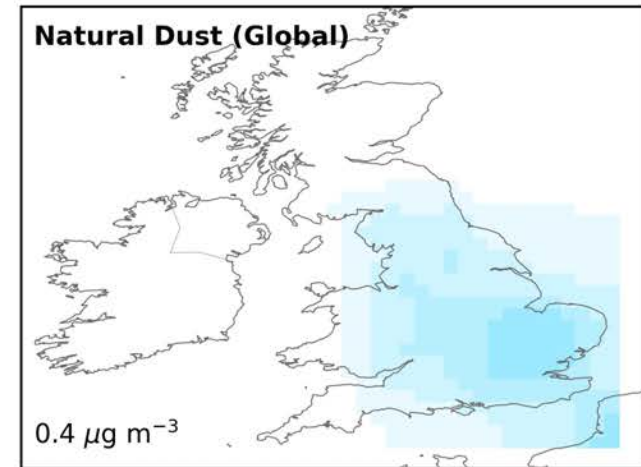
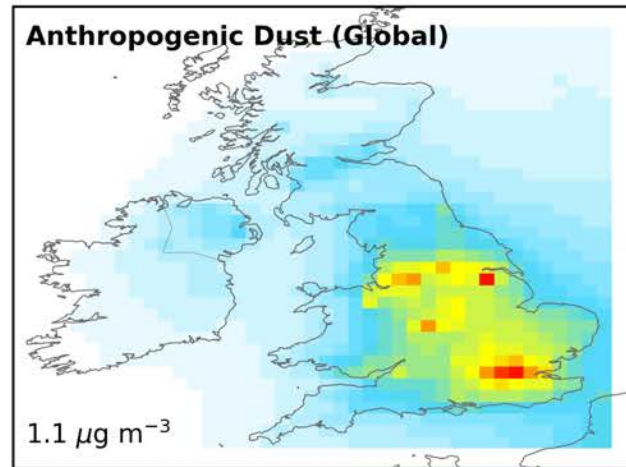
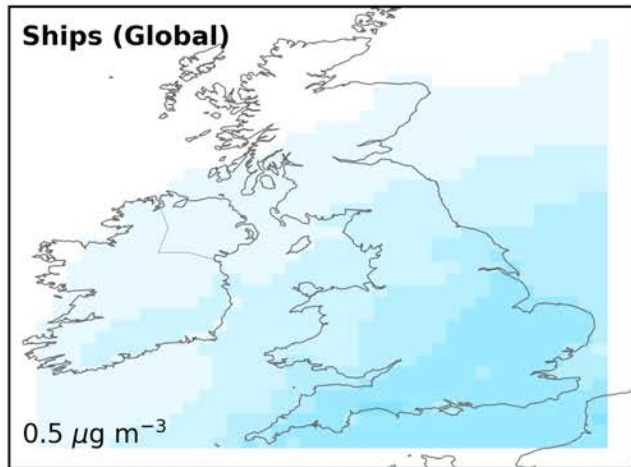
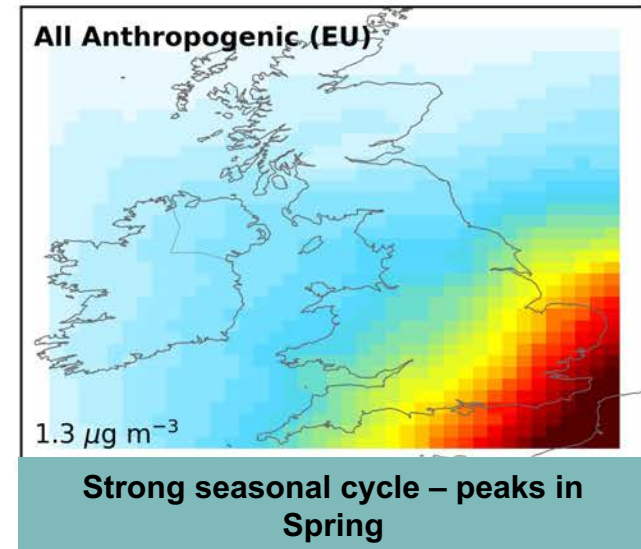
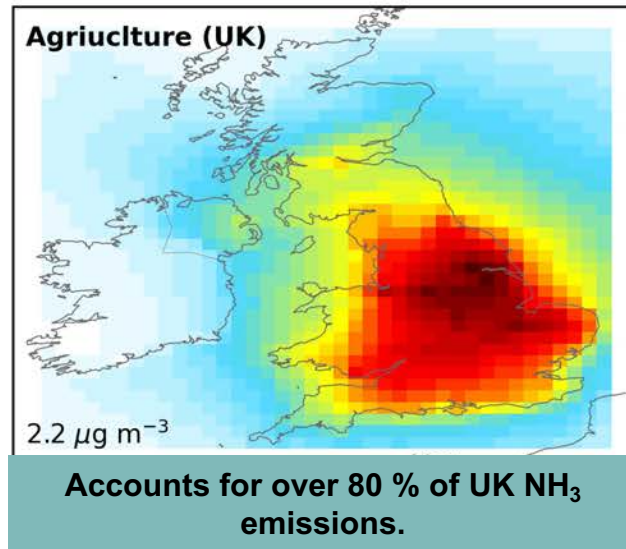
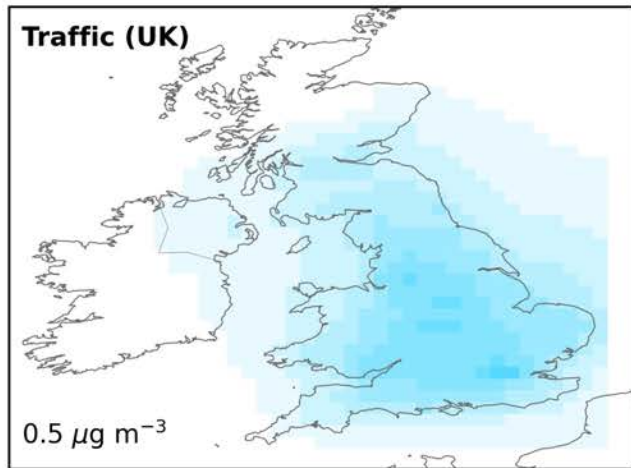
# Simulate $\text{PM}_{2.5}$ with the 3D Model GEOS-Chem

3D Atmospheric Chemistry Transport Model



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

# Contribution of Sources to UK PM<sub>2.5</sub>



# 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**



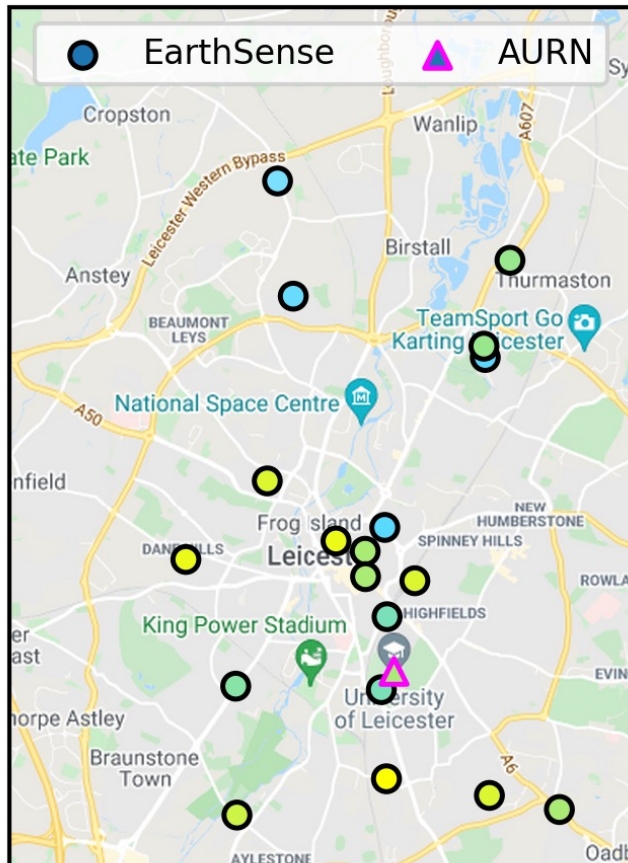
# Corroborating Evidence from Low-Cost Sensors

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

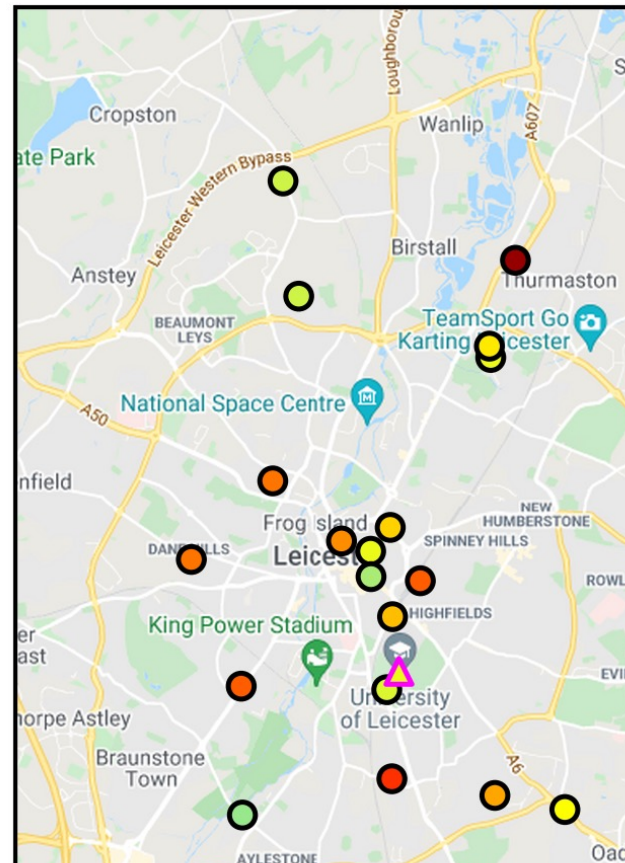


# Corroborating Evidence from Low-Cost Sensors

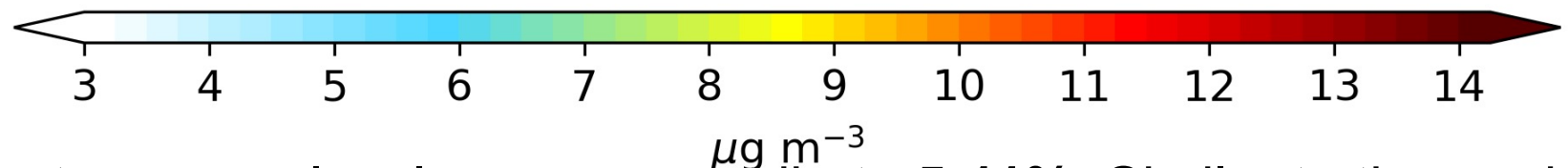
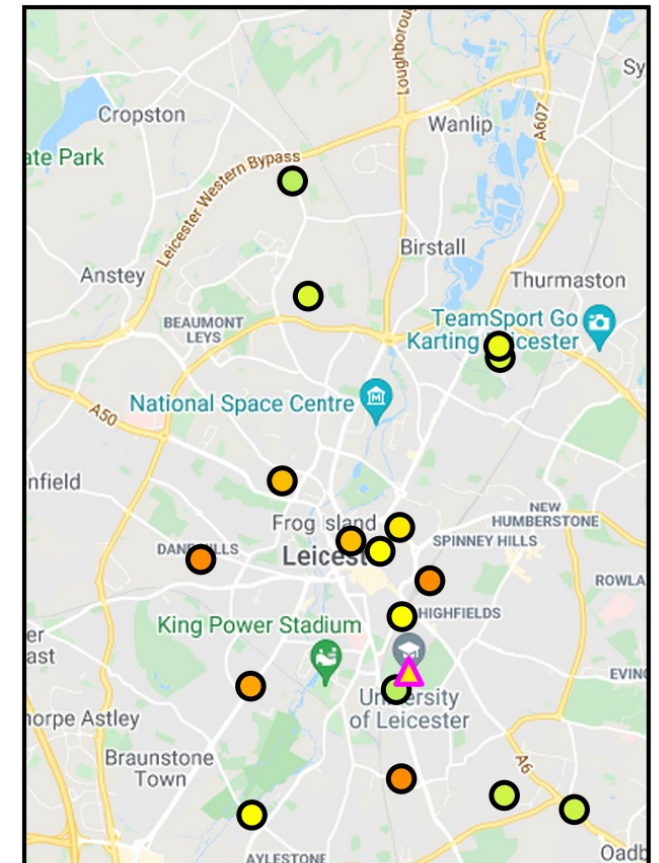
December 2020



January 2021



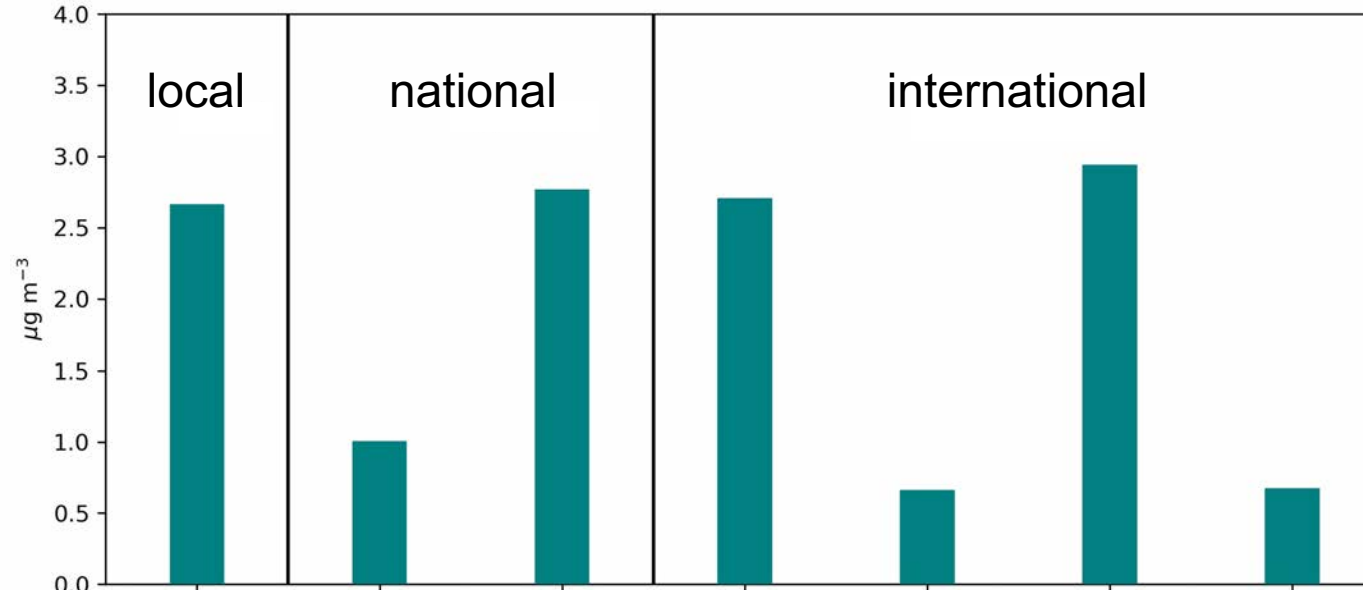
February 2021



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

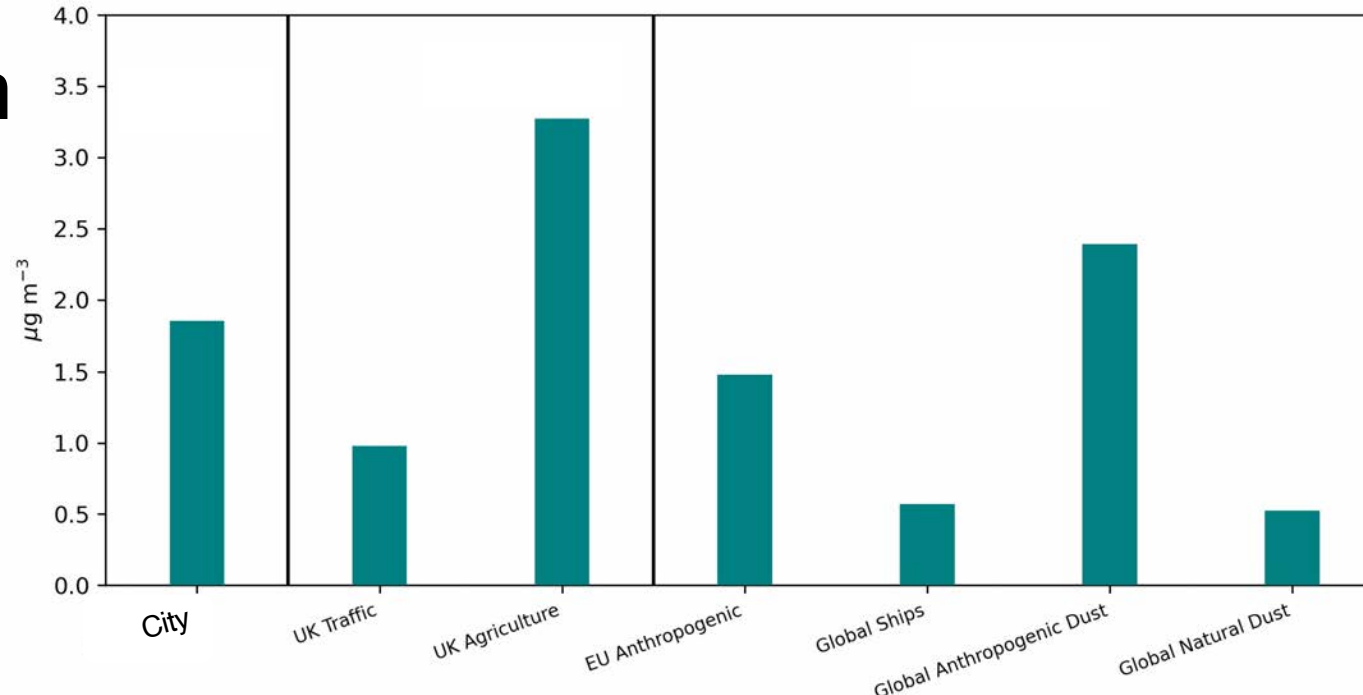
# Results for Large Cities like London and Birmingham

London



**London:** 1,600 km<sup>2</sup>  
**Birmingham:** 270 km<sup>2</sup>  
**Leicester:** 70 km<sup>2</sup>

Birmingham



Broad applicability to other cities

Only in London is local PM<sub>2.5</sub> 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  
Food & Rural Affairs

## Local Authorities

City  
Councils



Camden



Leicester  
City Council

### 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

**Thanks for  
listening!**

- Unregulated agriculture dominates PM<sub>2.5</sub> year-round
- Mainland Europe makes large seasonal contribution to PM<sub>2.5</sub> 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



Department  
for Environment  
Food & Rural Affairs