# Satellites up above monitor the air down below!!!





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*West Midlands Speak Out For Engineering Heats (17th Oct'19)*

# The Problem

Exposure to fine particles caused 4.2 millions deaths worldwide in 2015 representing 7.6% of global deaths

*Cohen et al., 2017*

Air pollution may be damaging 'every organ in the body'

*Schraufnagel et al, 2019*

Estimated excess mortality attributed to air pollution in Europe

*European Heart Journal, 2019*

Air pollution takes decade off memory, study suggests

*The Times, 2019*

Pollution map reveals unsafe air quality at almost 2,000 UK sites

*The Guardian, 2019*

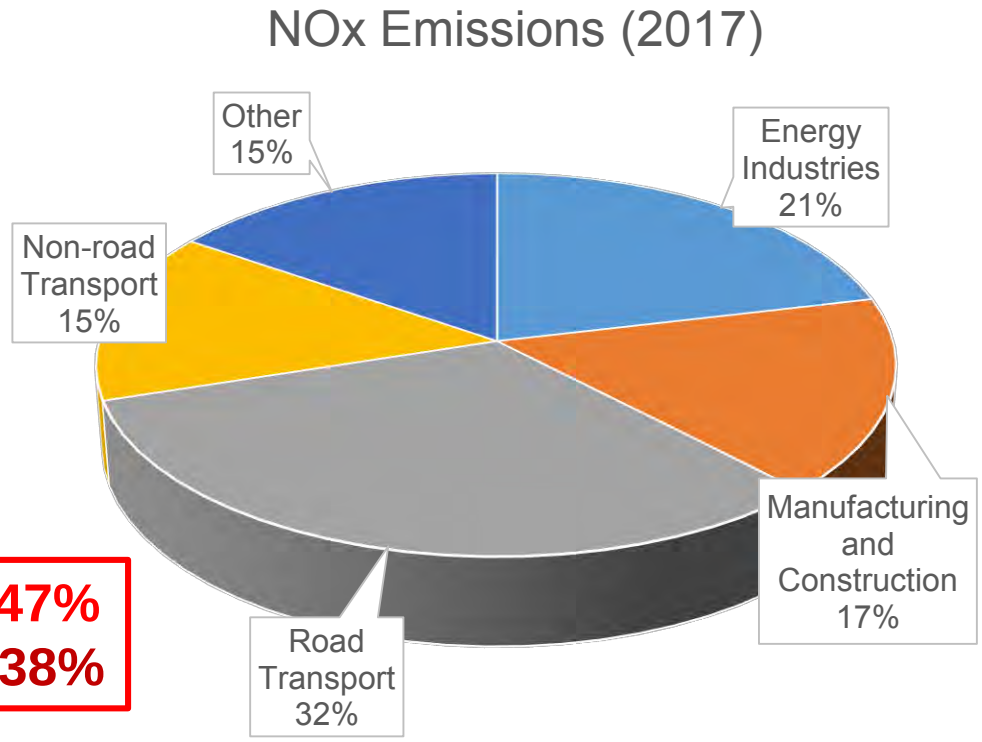
Study links air pollution exposure to miscarriages

*Zhang et al., 2019*

What's common???

## Nitrogen dioxide ($NO_2$)

But where is it coming from???

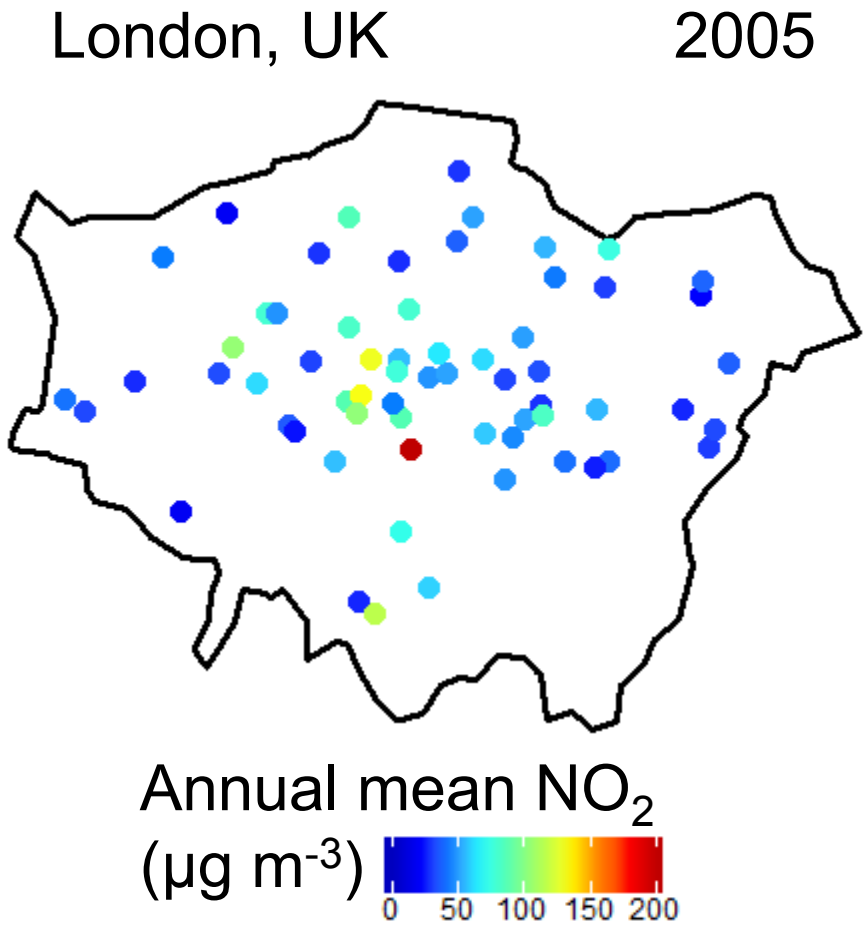



**Transport: 47%**
**Industries: 38%**

*Data from National Atmospheric Emissions Inventory*

# The Current Approach

Surface monitoring networks have their limitations

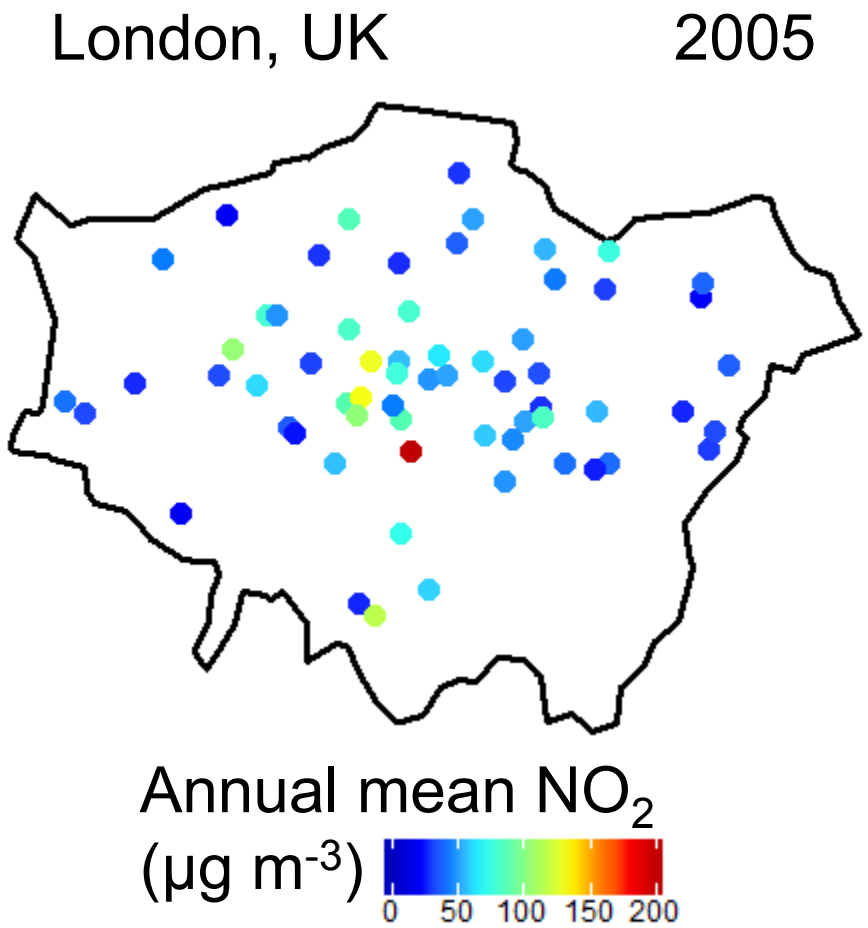



Data from *London Air Quality Network (LAQN)*

# The Current Approach

Surface monitoring networks have their limitations

- ❑ Expensive to set up and maintain

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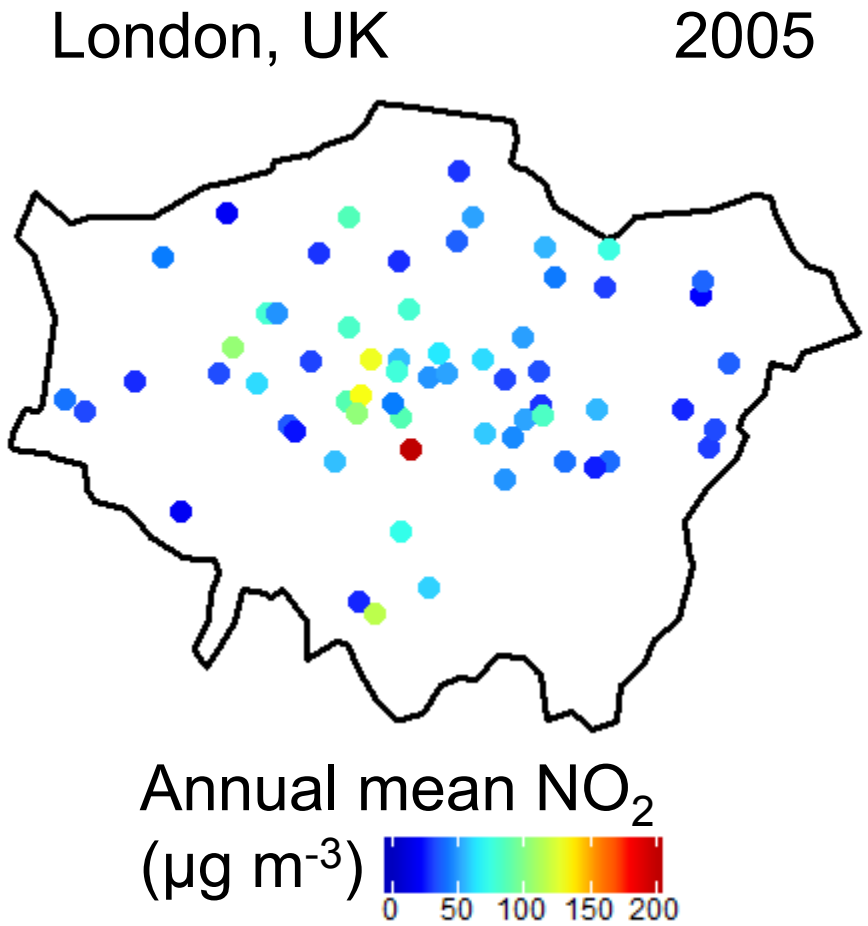


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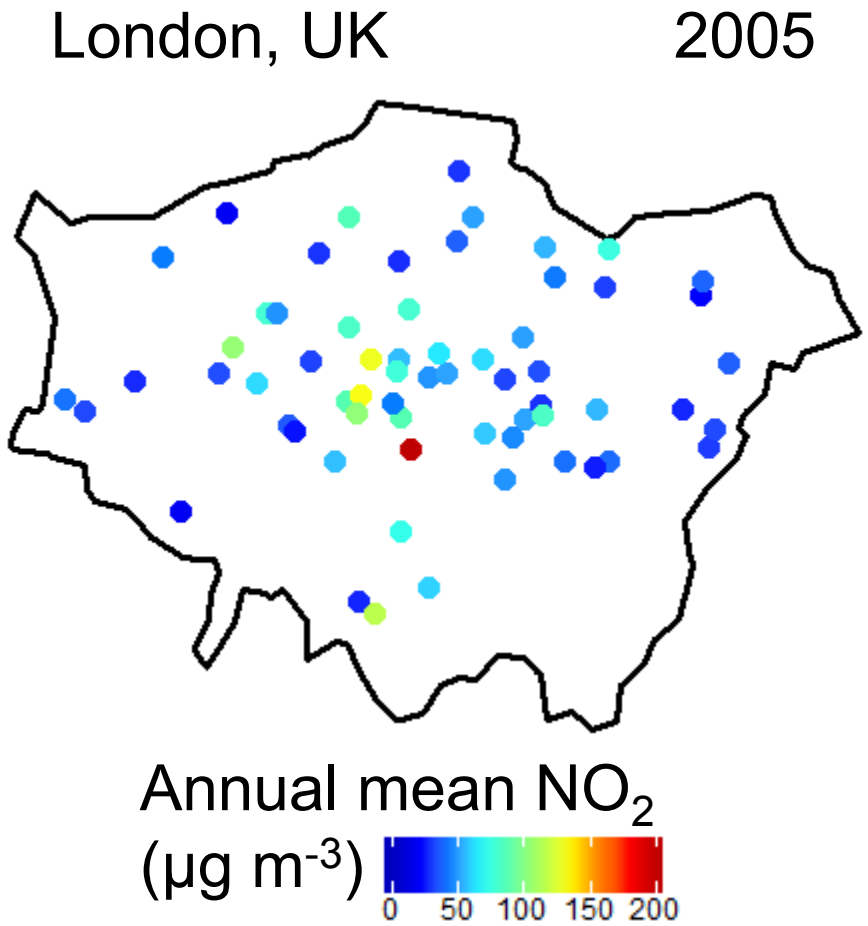


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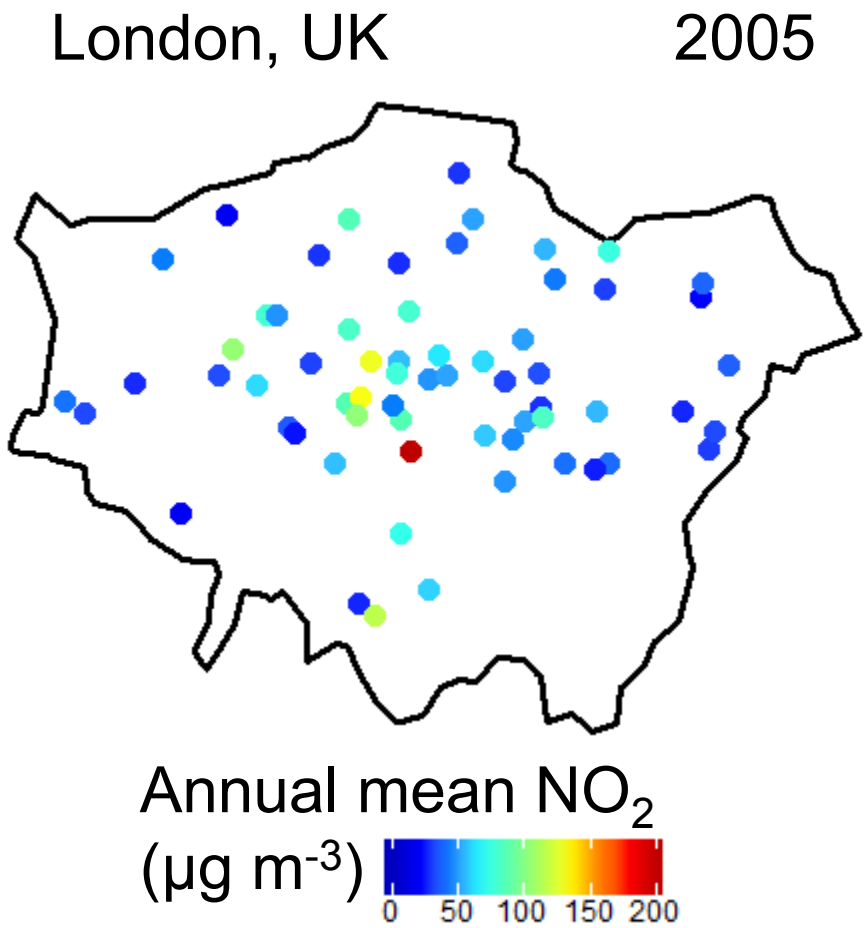
# The Current Approach

Surface monitoring networks have their limitations

- ❑ Expensive to set up and maintain
- ❑ Limited spatial and temporal coverage
- ❑ Limited pollutants monitored
- ❑ Issues with data quality

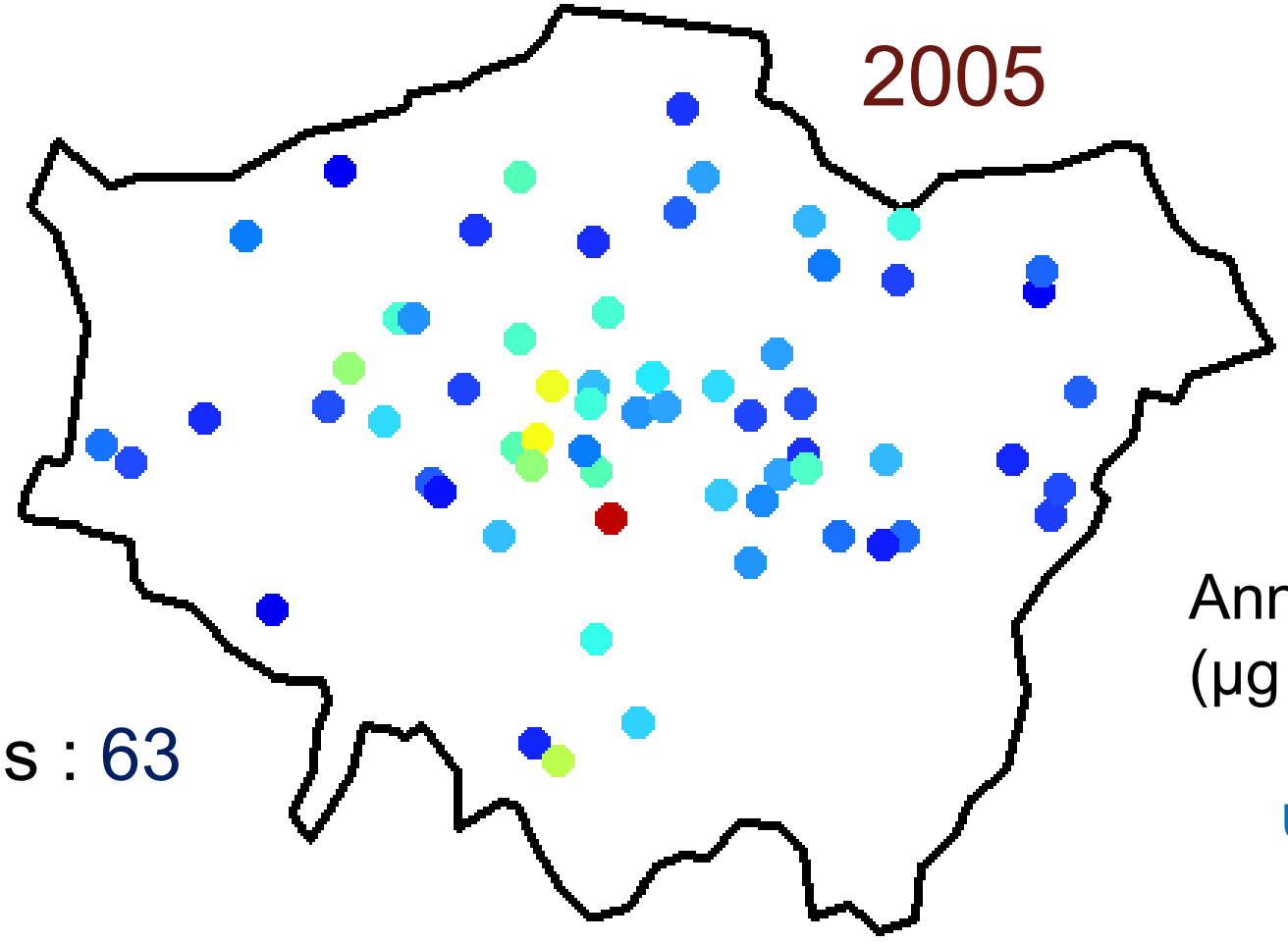



Data from *London Air Quality Network (LAQN)*

# The Current Approach

- Inconsistent (sites come and go over time)

London, UK




Number of sites : 63

Annual mean $NO_2$ ($\mu g\ m^{-3}$)

0 50 100 150 200

UK annual mean $NO_2$ limit (40 $\mu g\ m^{-3}$)

Data from *London Air Quality Network (LAQN)*

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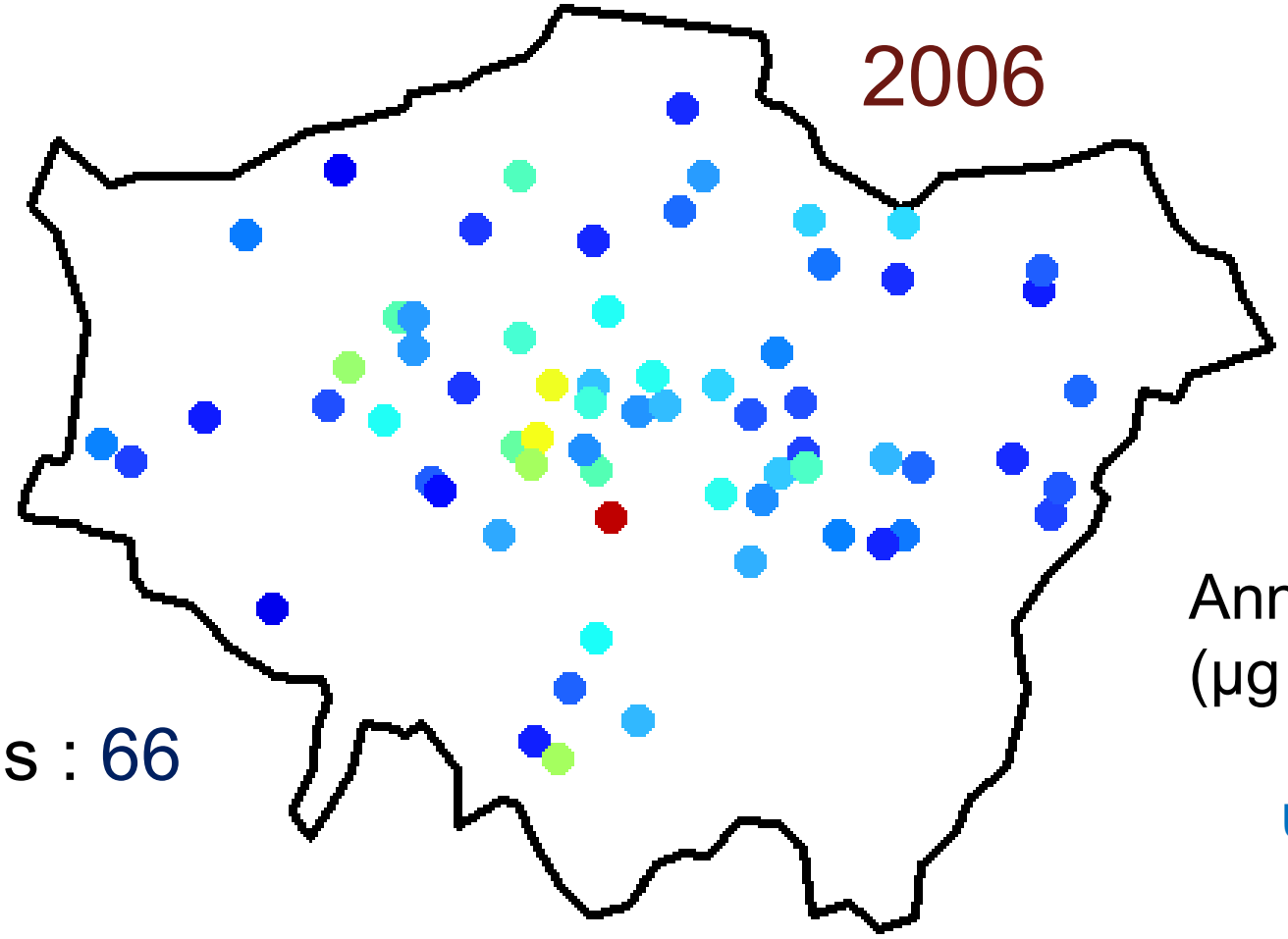


Number of sites : 66

Annual mean $NO_2$ ($\mu g\ m^{-3}$)

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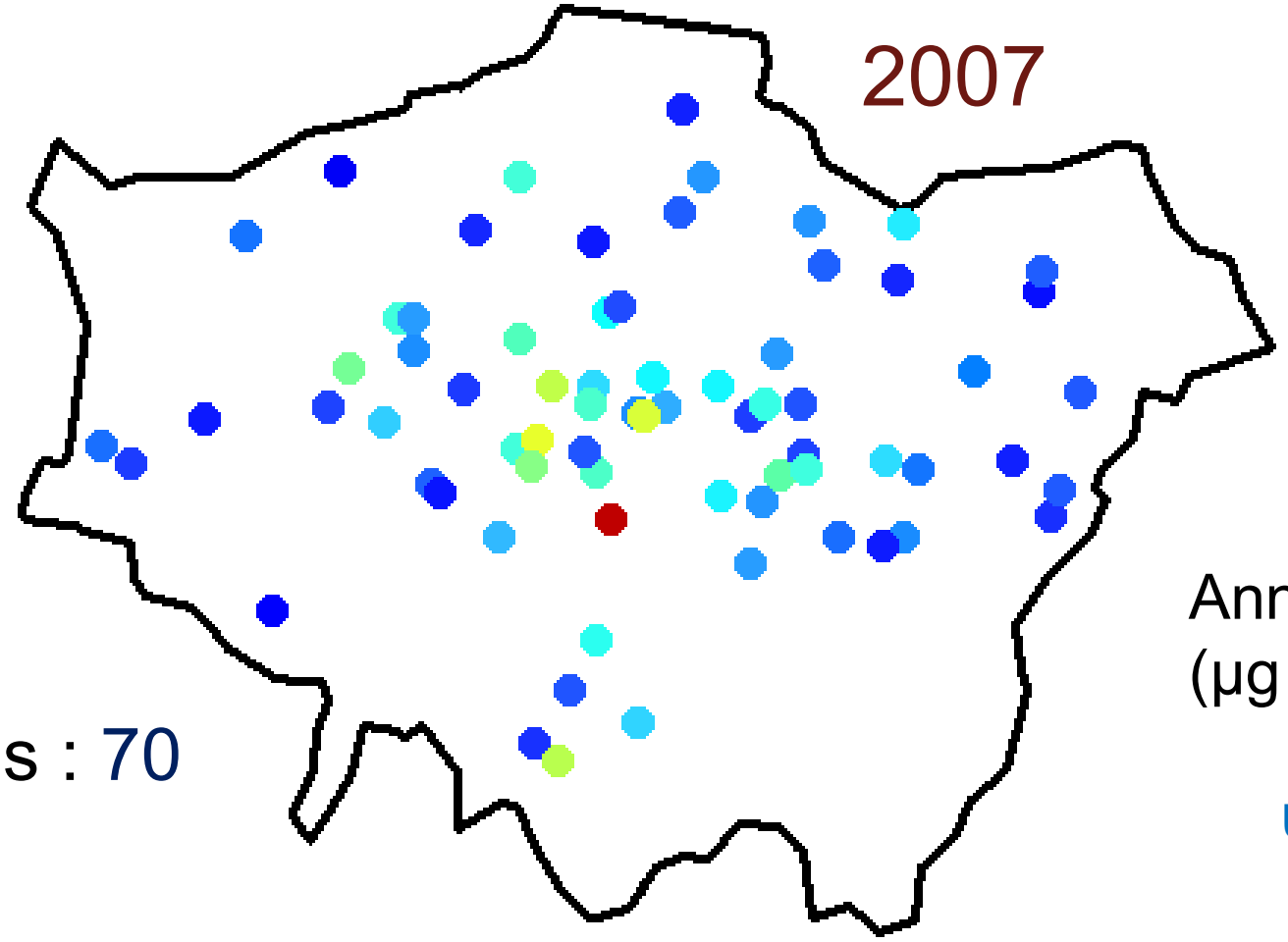


Number of sites : 70

Annual mean $NO_2$ ($\mu g\ m^{-3}$)

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UK annual mean $NO_2$ limit (40 $\mu g\ m^{-3}$)

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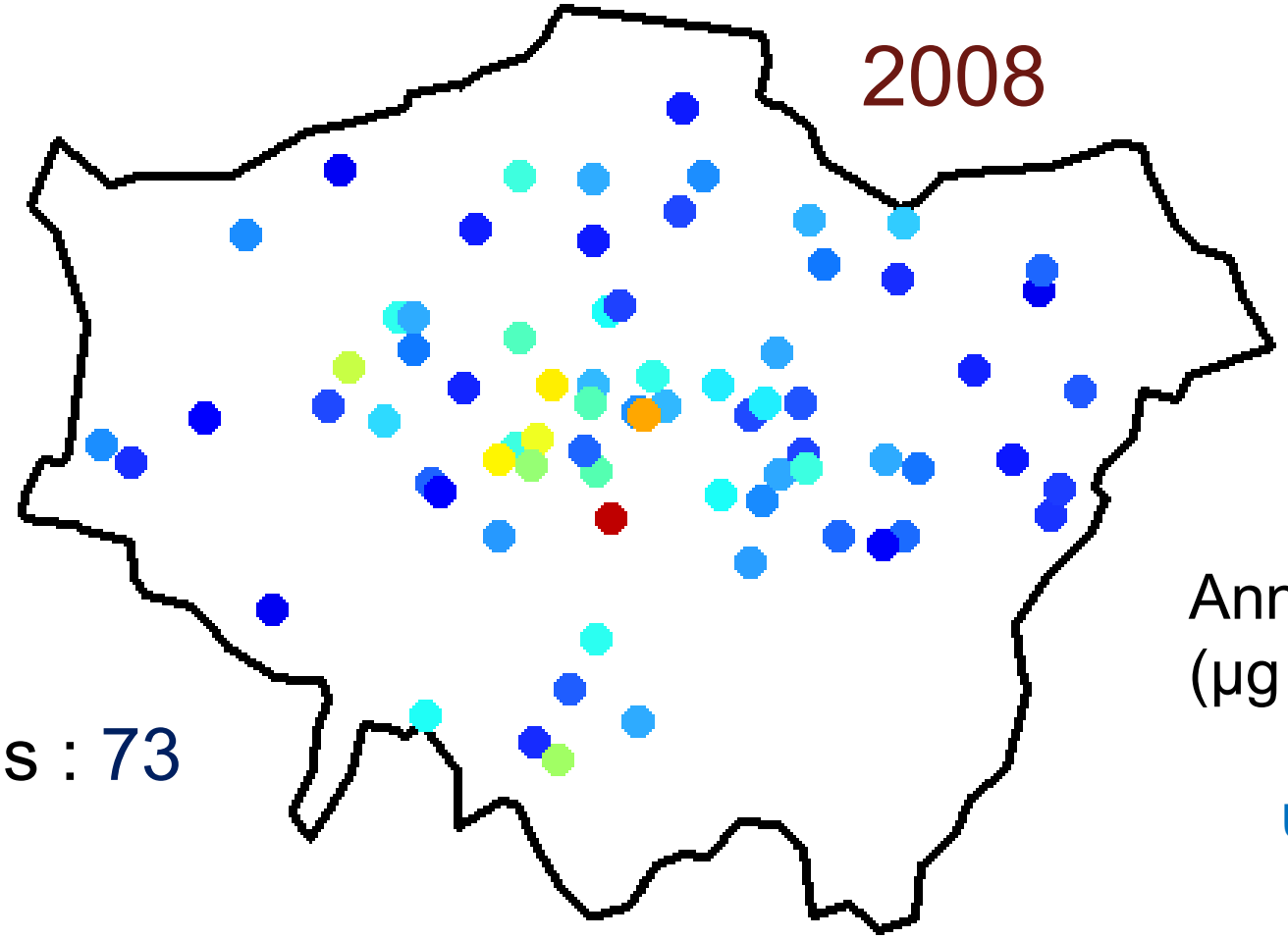


Number of sites : 73

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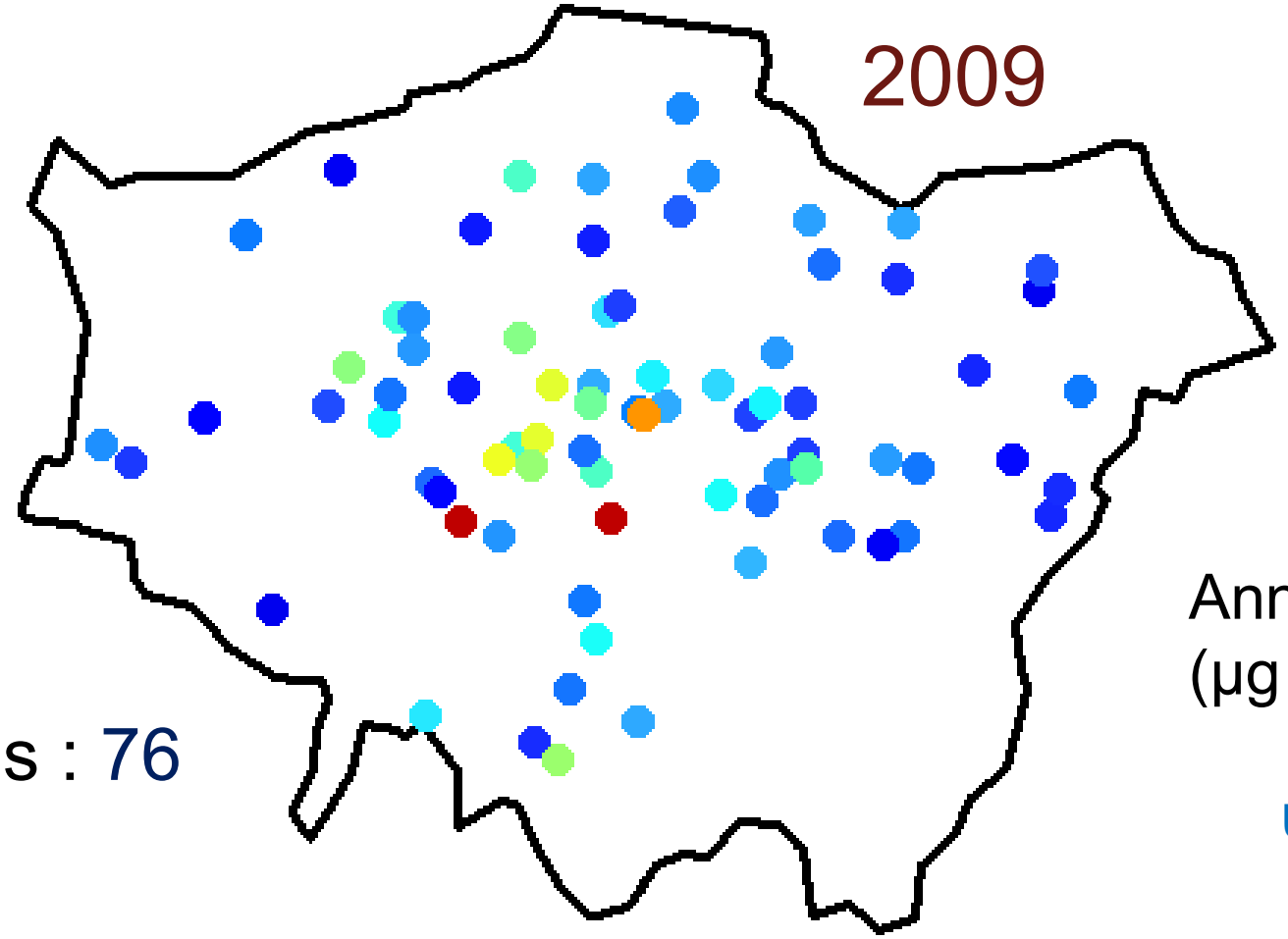


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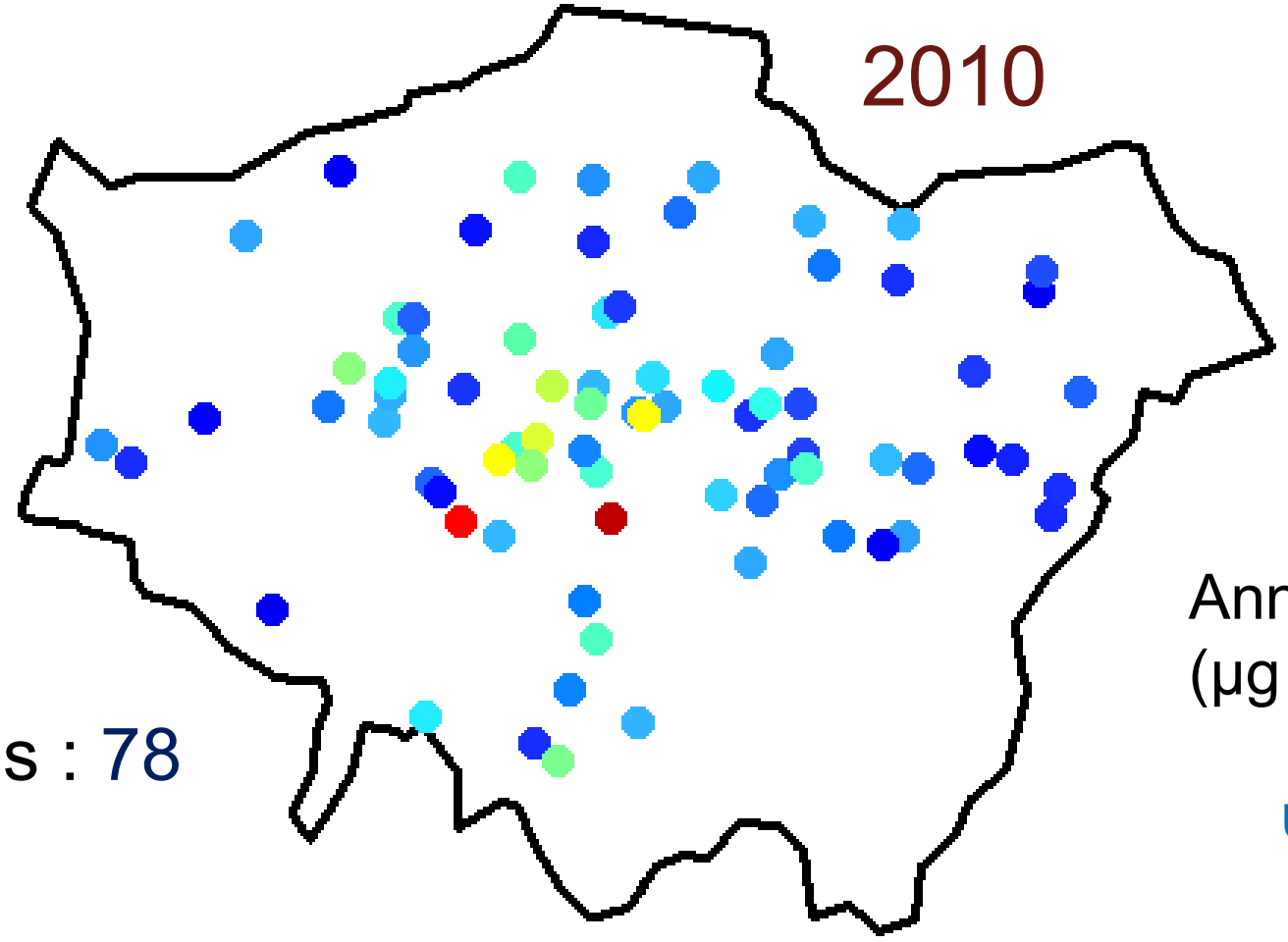


Number of sites : 78

Annual mean $NO_2$ ($\mu g\ m^{-3}$)

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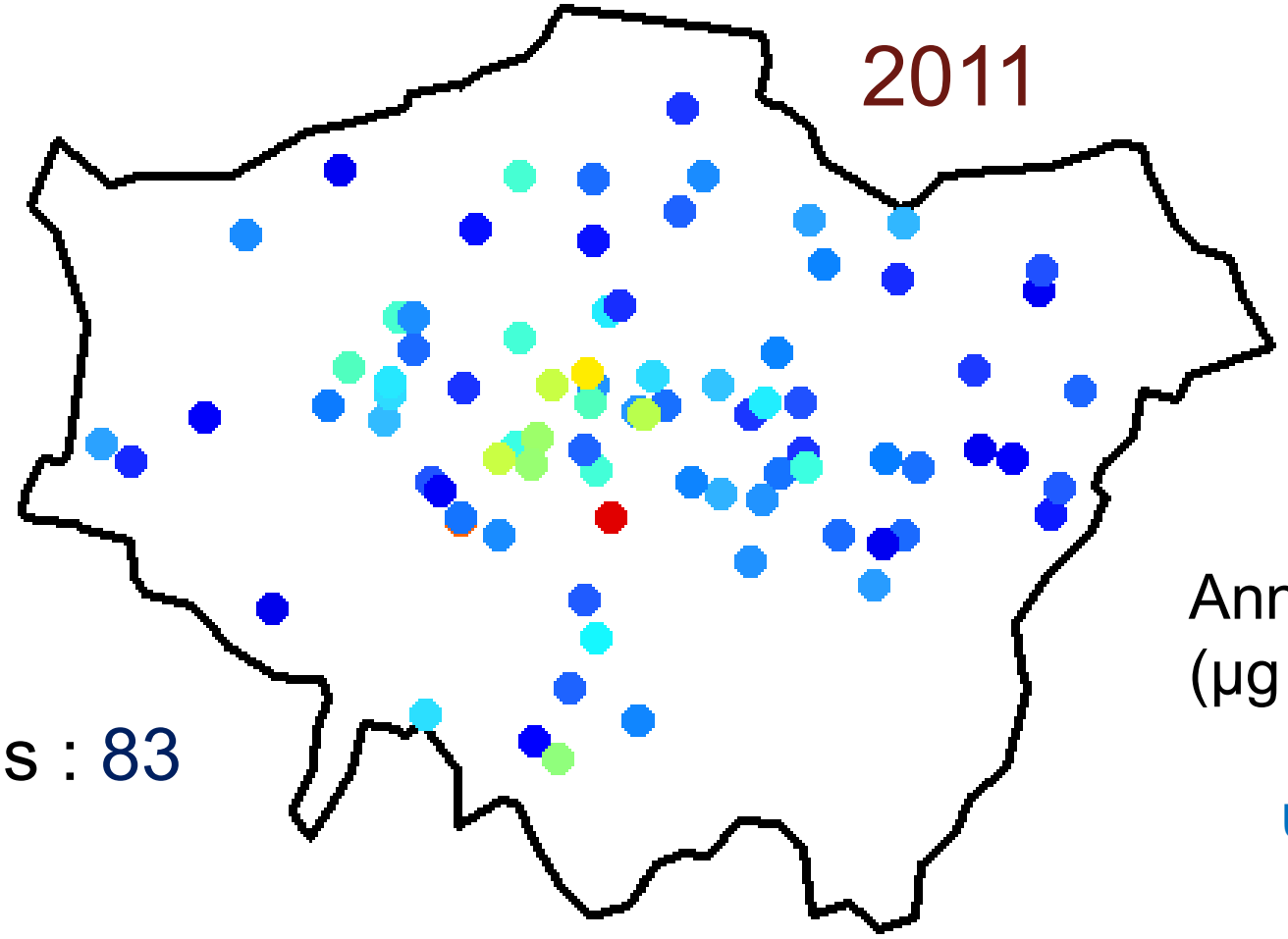


Number of sites : 83

Annual mean $NO_2$ ($\mu g\ m^{-3}$)

0 50 100 150 200

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Data from *London Air Quality Network (LAQN)*

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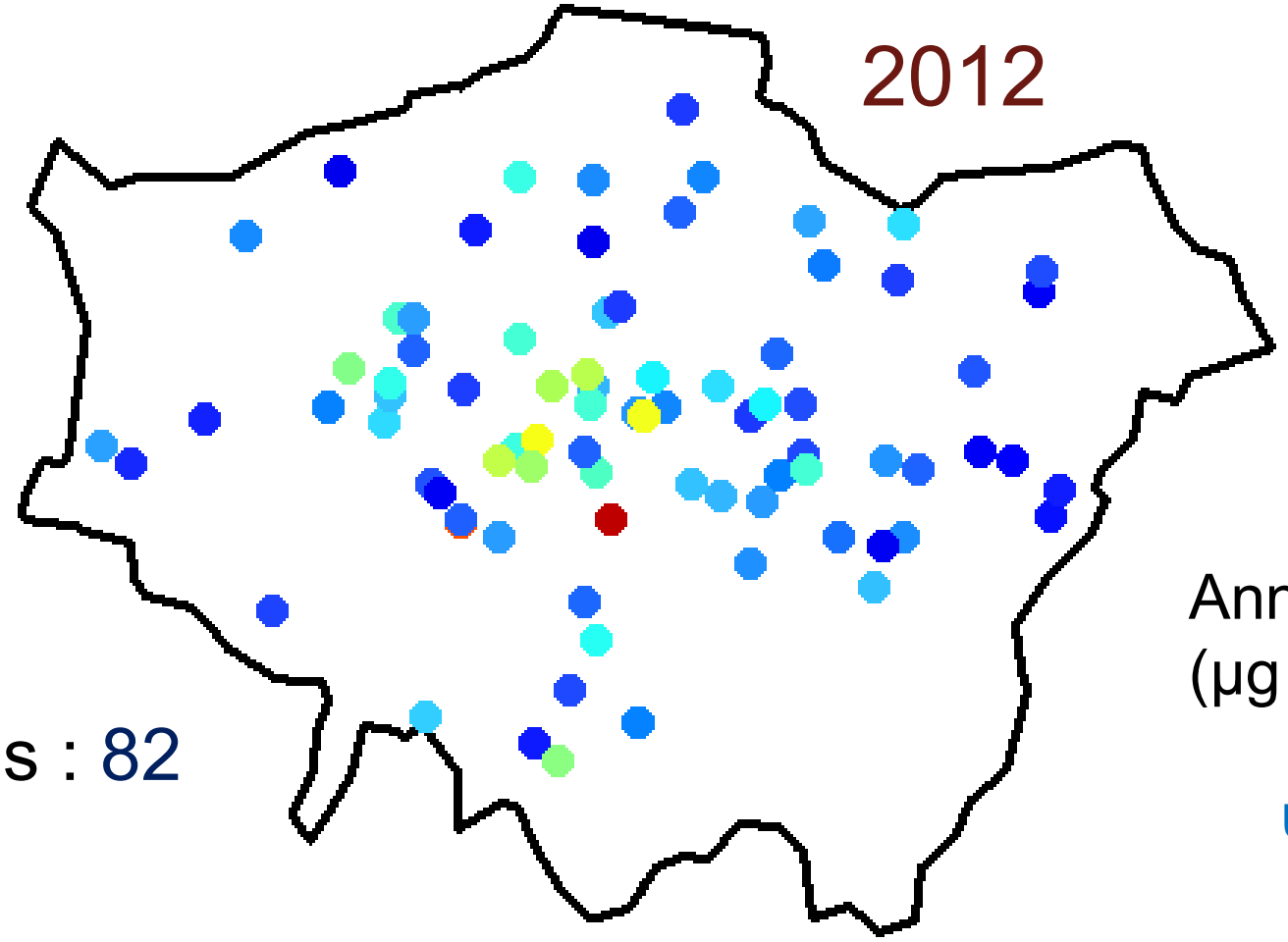


Number of sites : 82

Annual mean $NO_2$ ($\mu g\ m^{-3}$)

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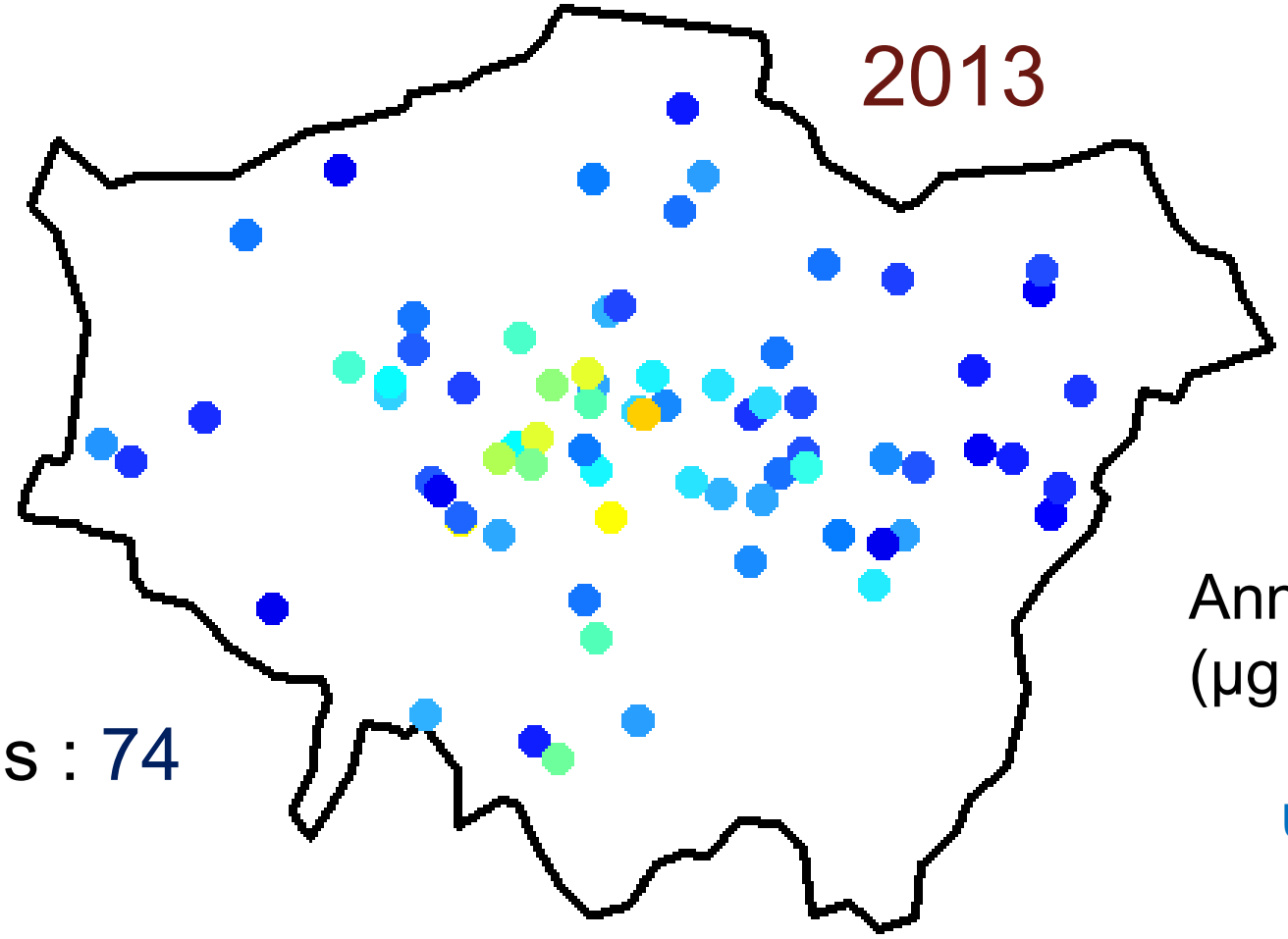


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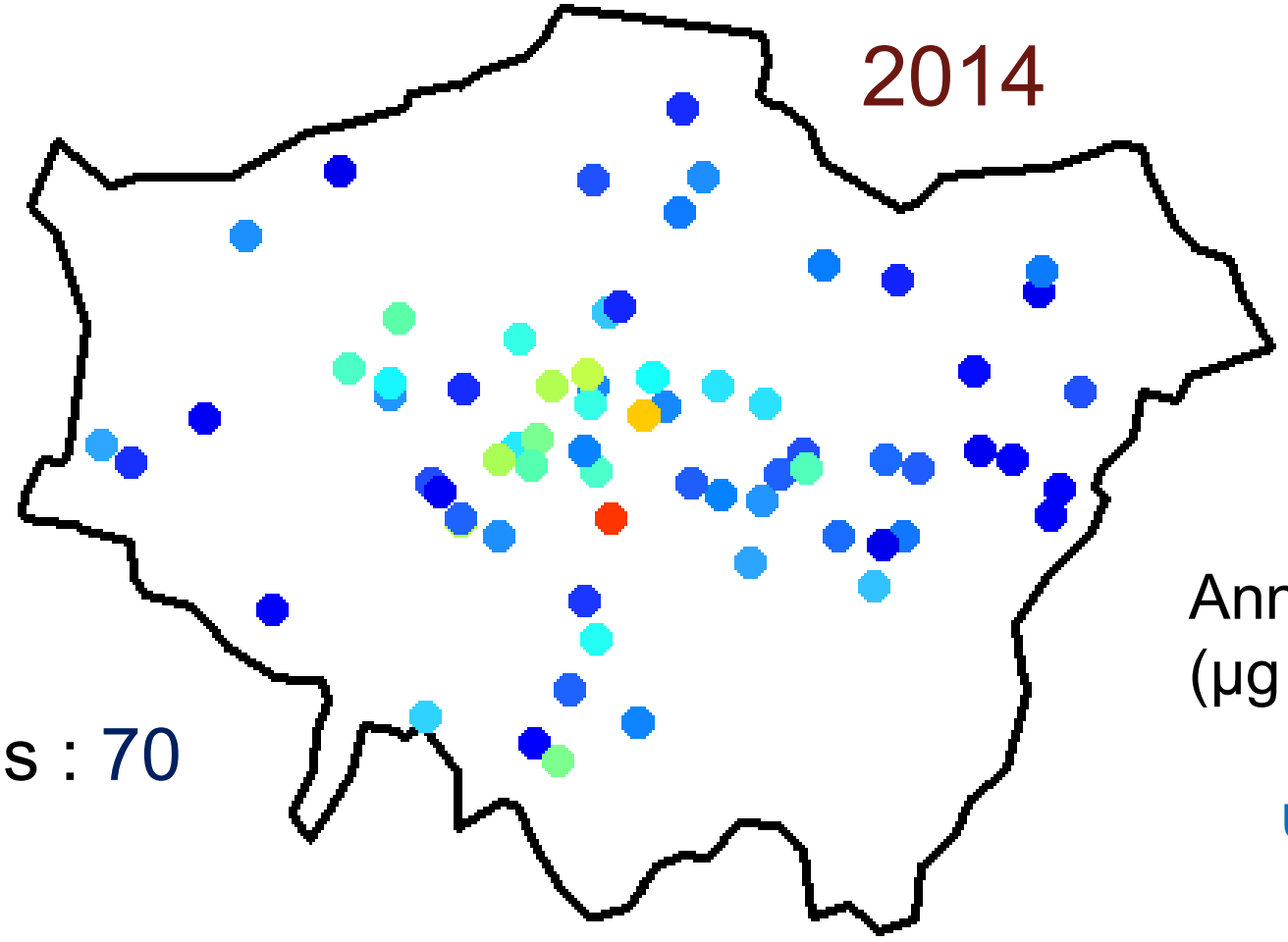


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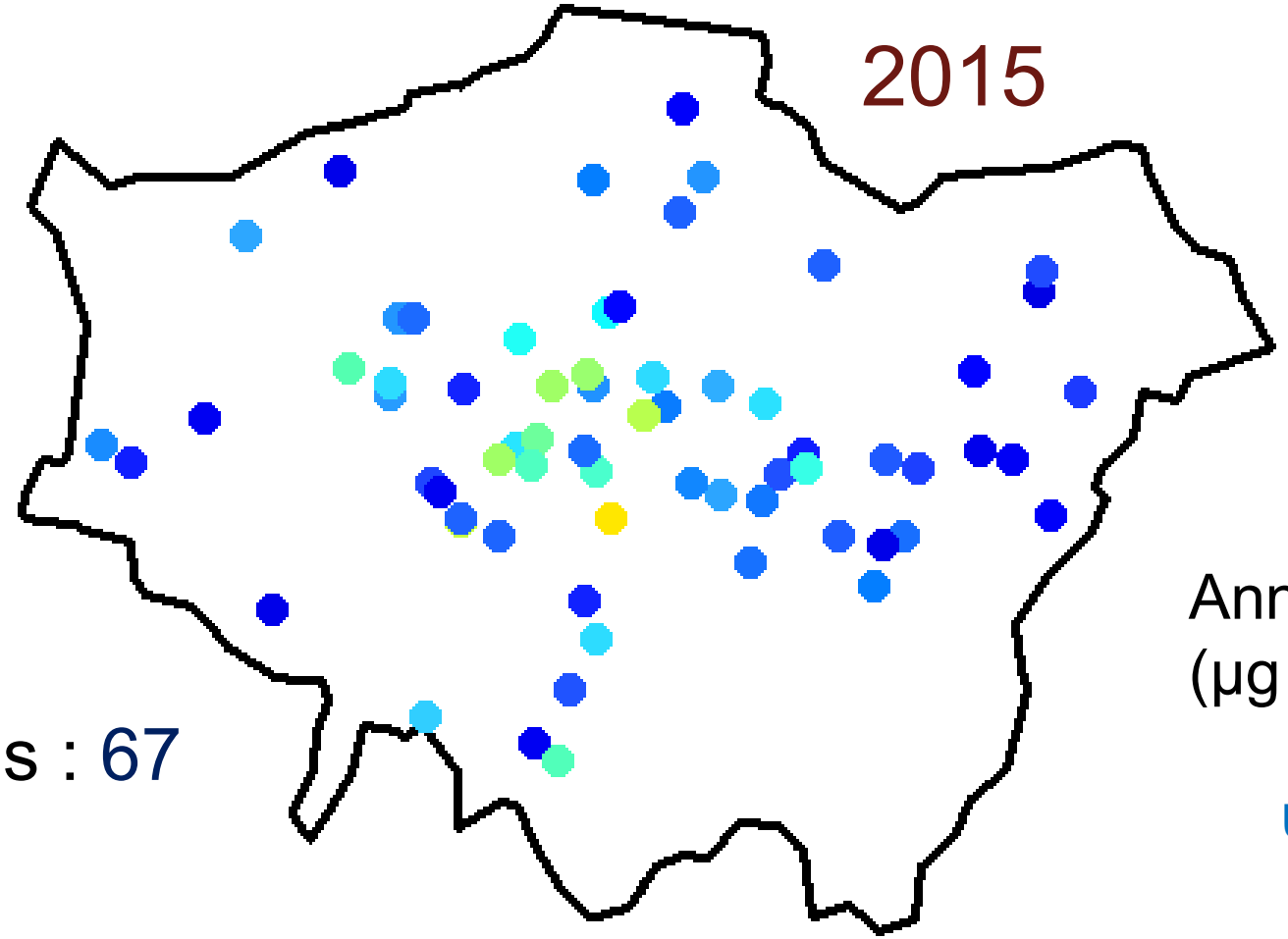


Number of sites : 67

Annual mean $NO_2$ ($\mu g\ m^{-3}$)

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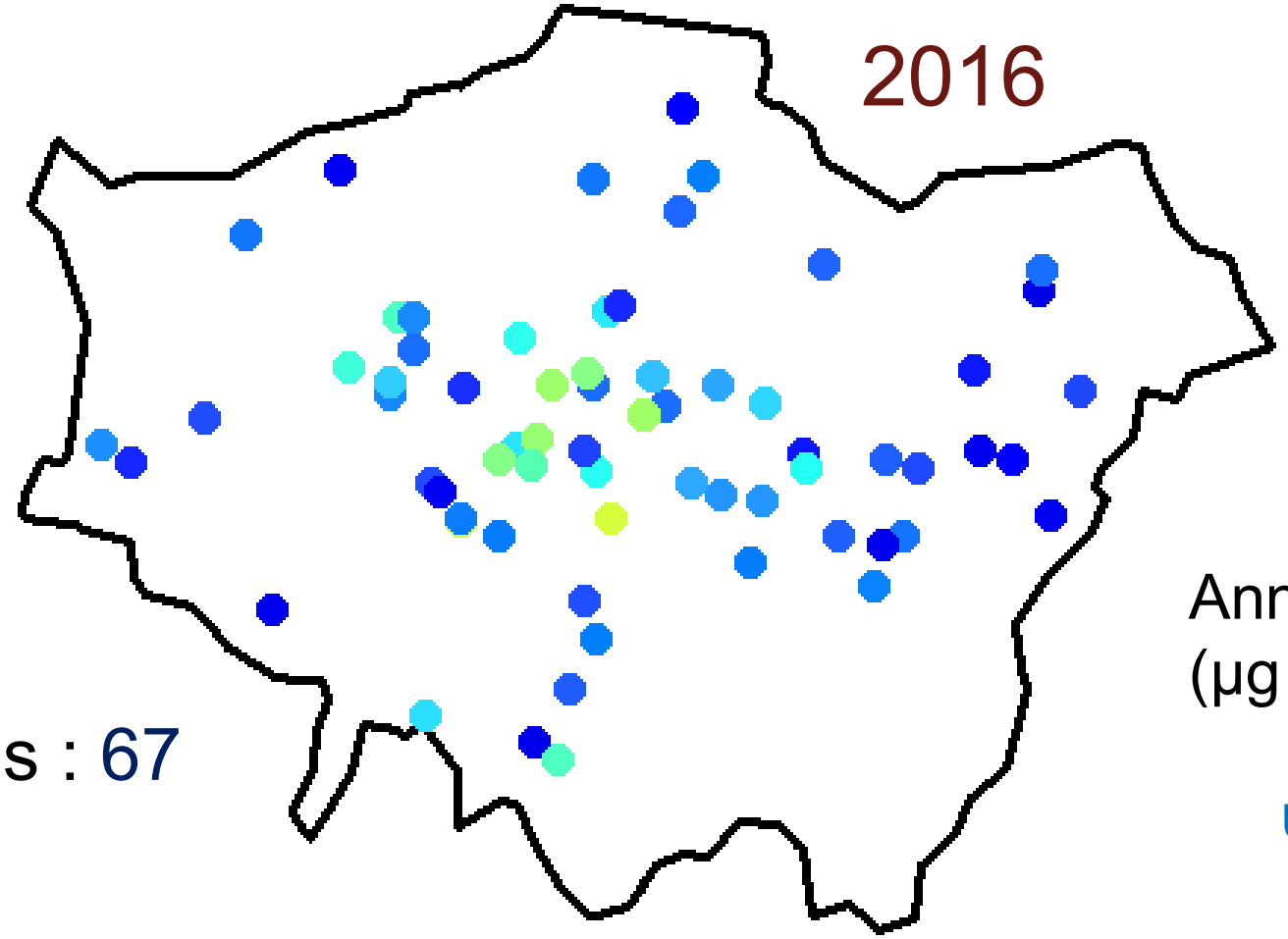


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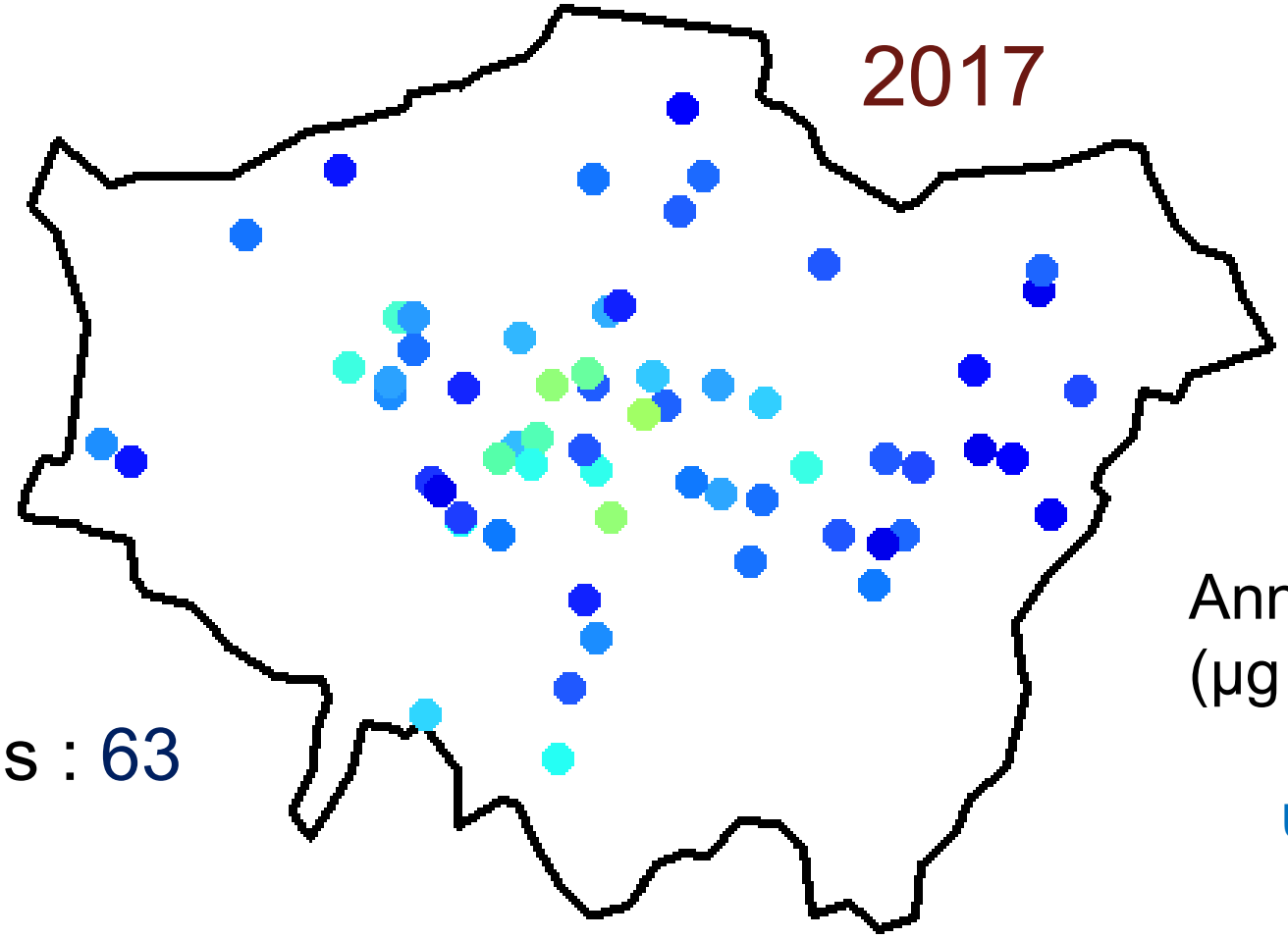


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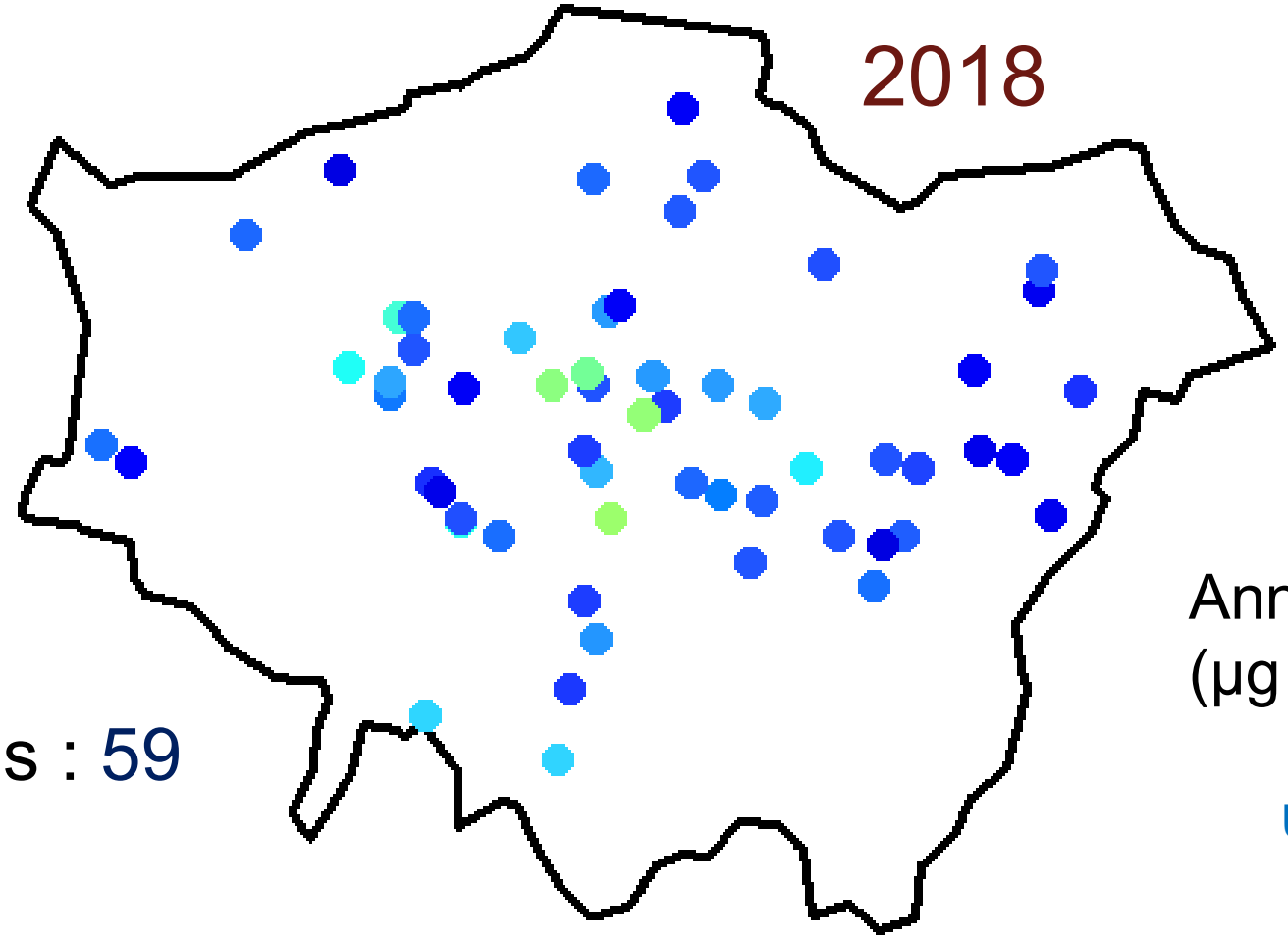



Number of sites : 59

Annual mean $NO_2$ ($\mu g\ m^{-3}$)

0 50 100 150 200

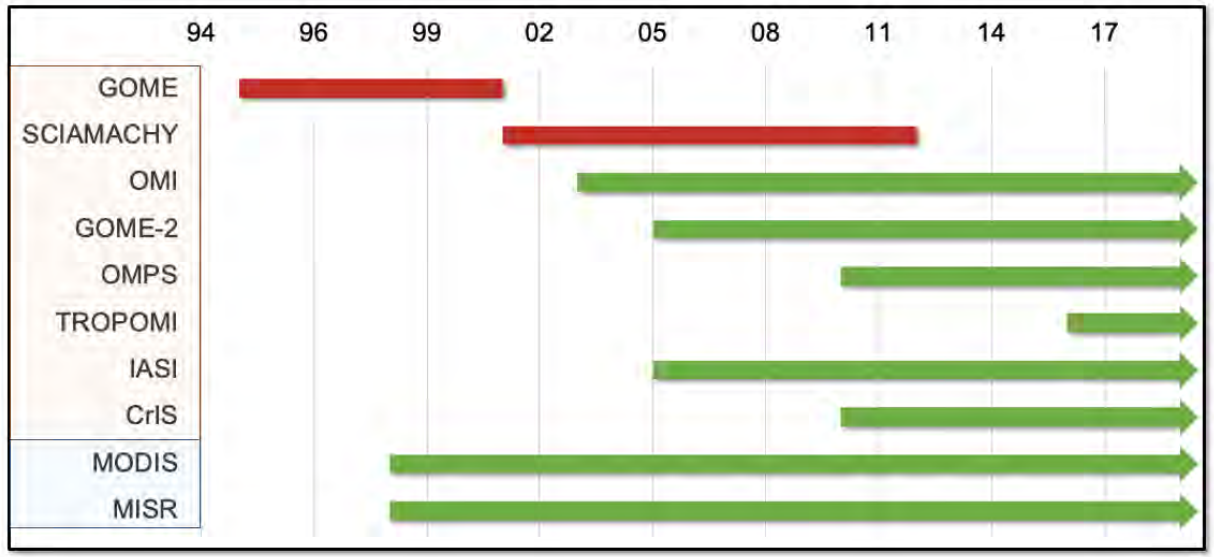
UK annual mean $NO_2$ limit (40 $\mu g\ m^{-3}$)

Data from *London Air Quality Network (LAQN)*

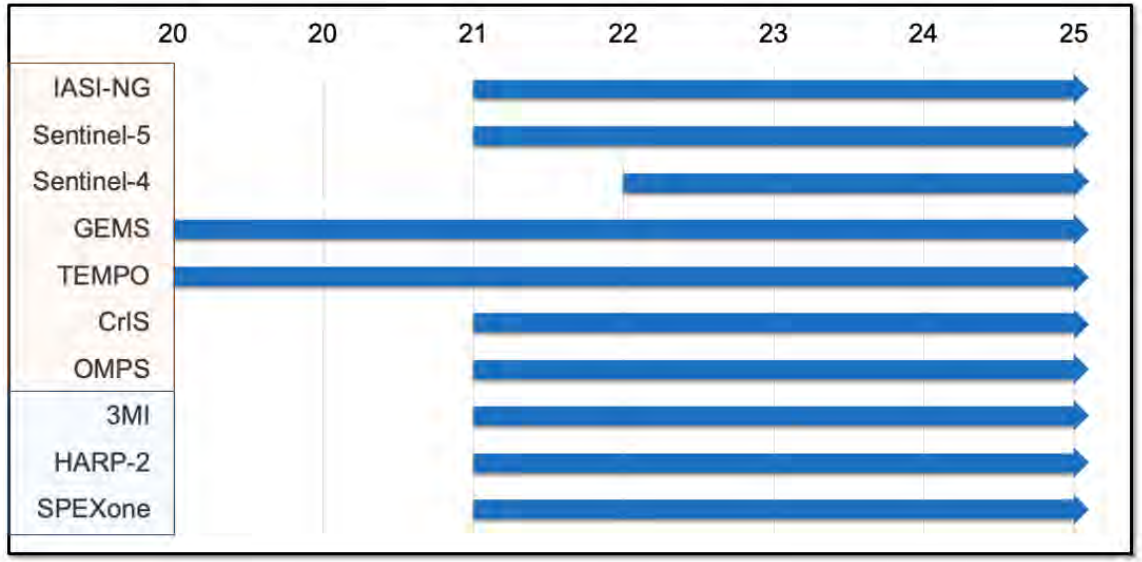
# The Solution

## Satellites are the only solution to address this global challenge

Sensors in space have been providing us with petabytes of data for more than 2 decades




Future missions will be cheaper and will have finer spatial resolution




Gases

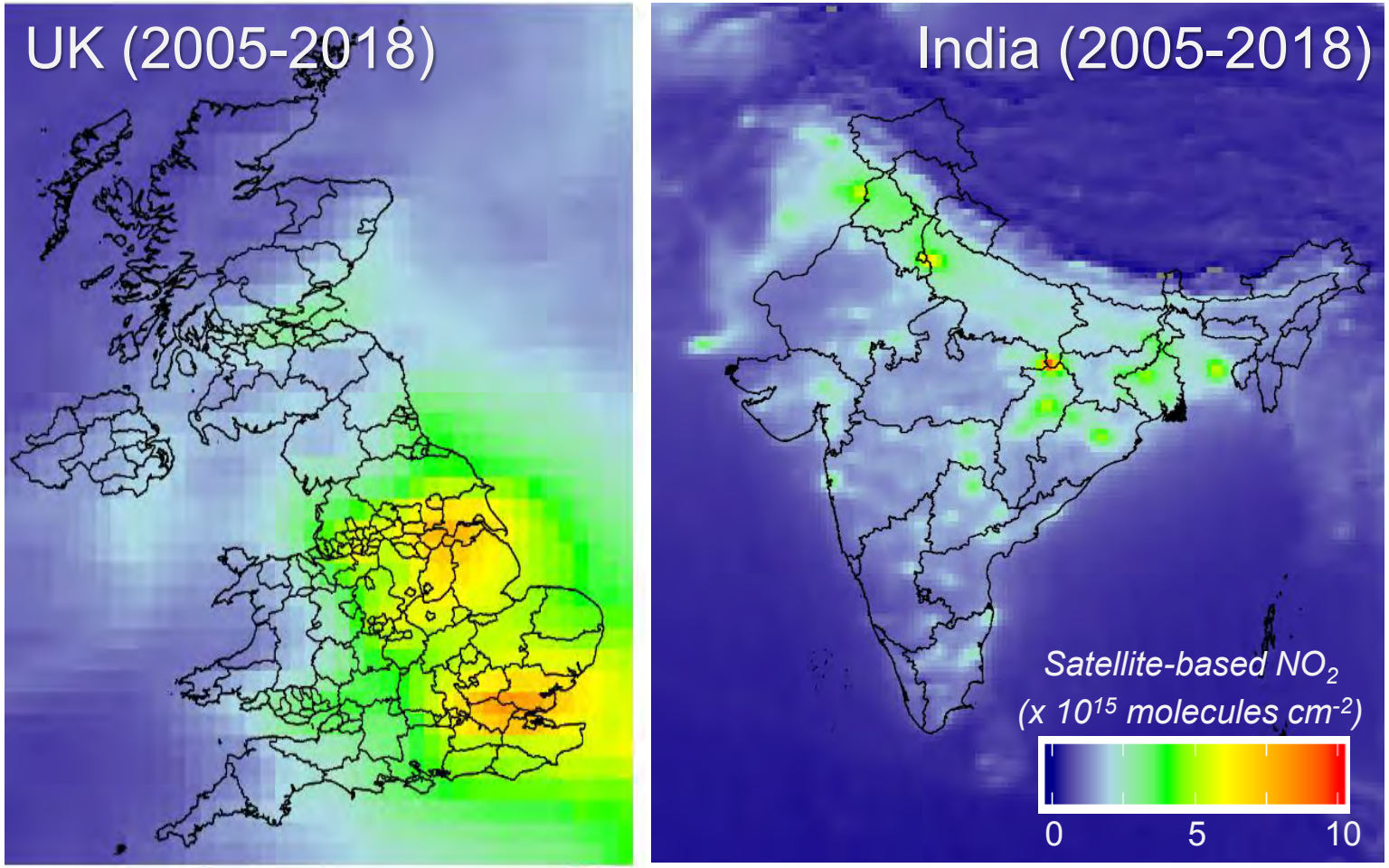
Particles

Completed

On-going

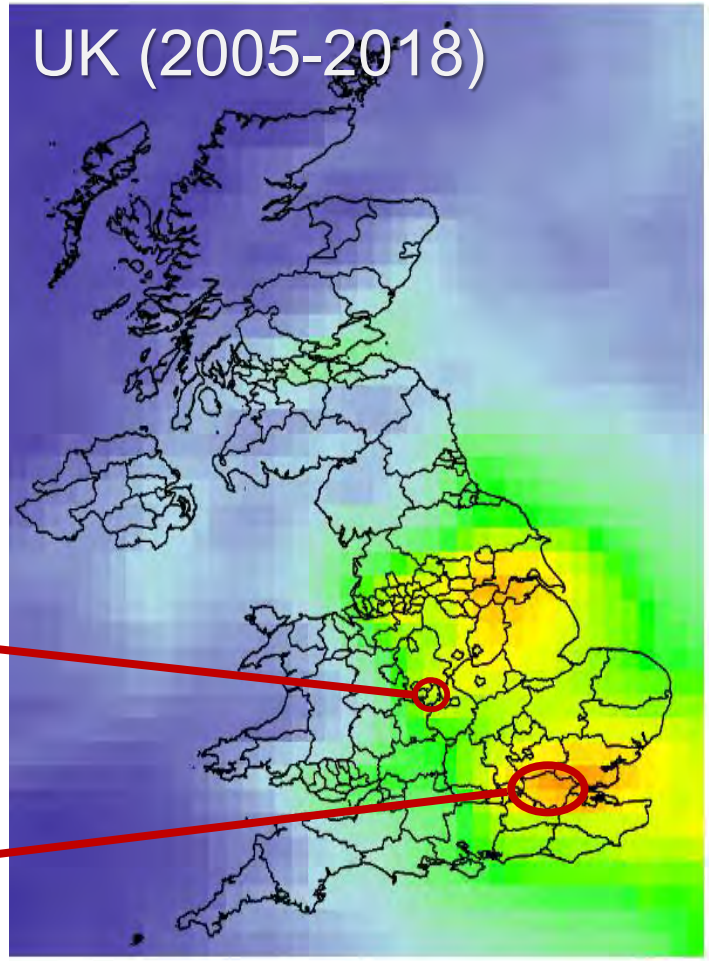
Future

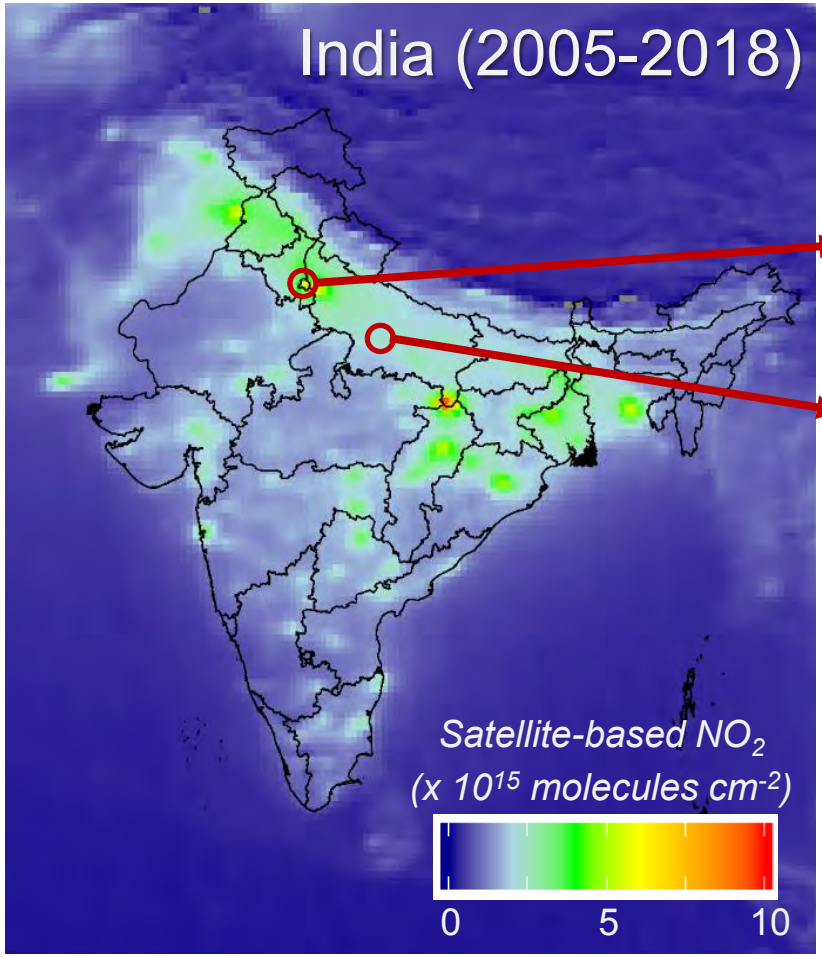
# Space-based instruments provide extensive data coverage



# Space-based instruments provide extensive data coverage

We develop our tool focusing on 4 dynamic cities




Birmingham

London

Delhi

Kanpur

The air around us is filled with pollutants

Air pollutants are emitted by multiple sources

Air pollutants undergo chemical reactions

And impact human health and food security

Satellites help monitor these air pollutants

NMVOCs (non-methane volatile organic compounds)

Intermediate product

OMI

HCHO (formaldehyde)

$O_3$ (ozone)

**Food security**

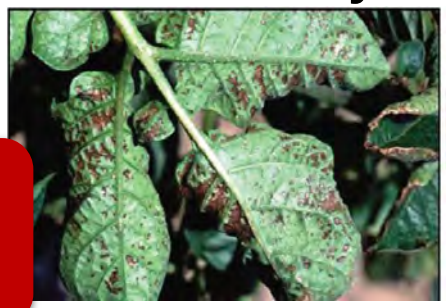
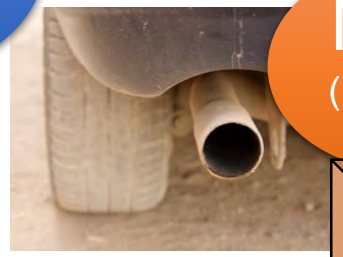


Photo credit: Dr Gerald Brust

OMI

$SO_X$ (sulphur oxides)



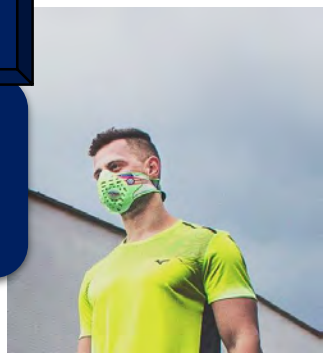
$NO_X$ (nitrogen oxides)

OMI

MODIS

$PM_{2.5}$ (particulate matter)

**Human health**



$NH_3$ (ammonia)

IASI

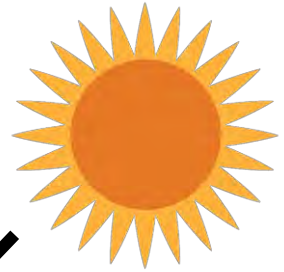
Primary particles

Pollutants

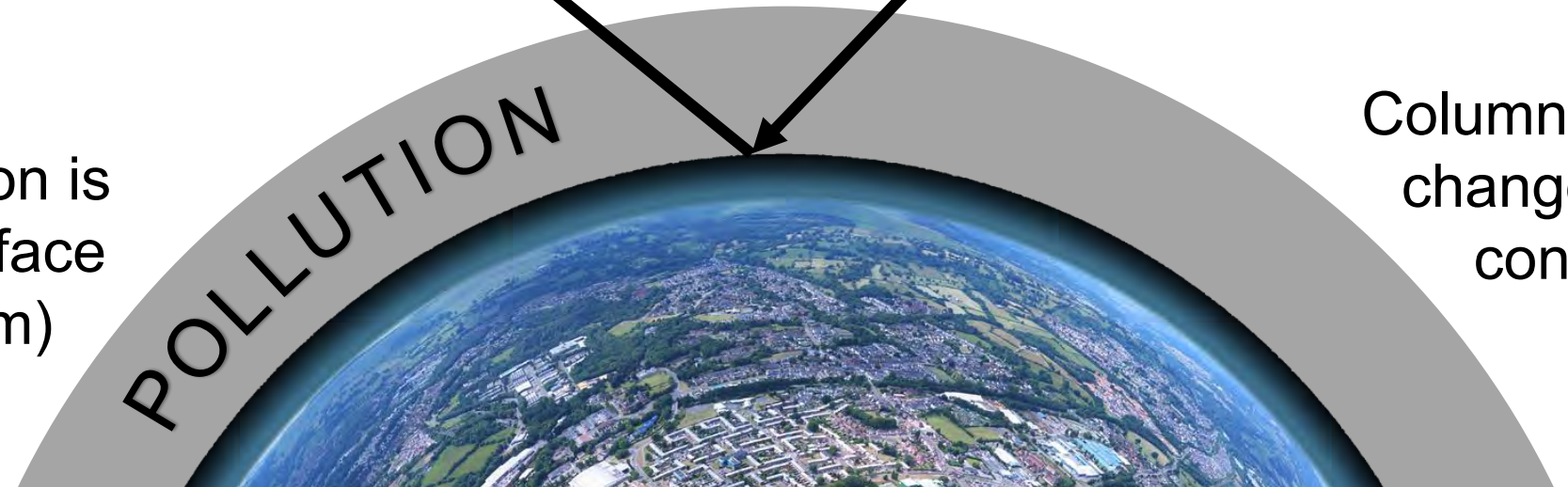
Instruments

# Satellite columns reflect changes in surface pollution


Satellite measures whole atmospheric column (>10 km)



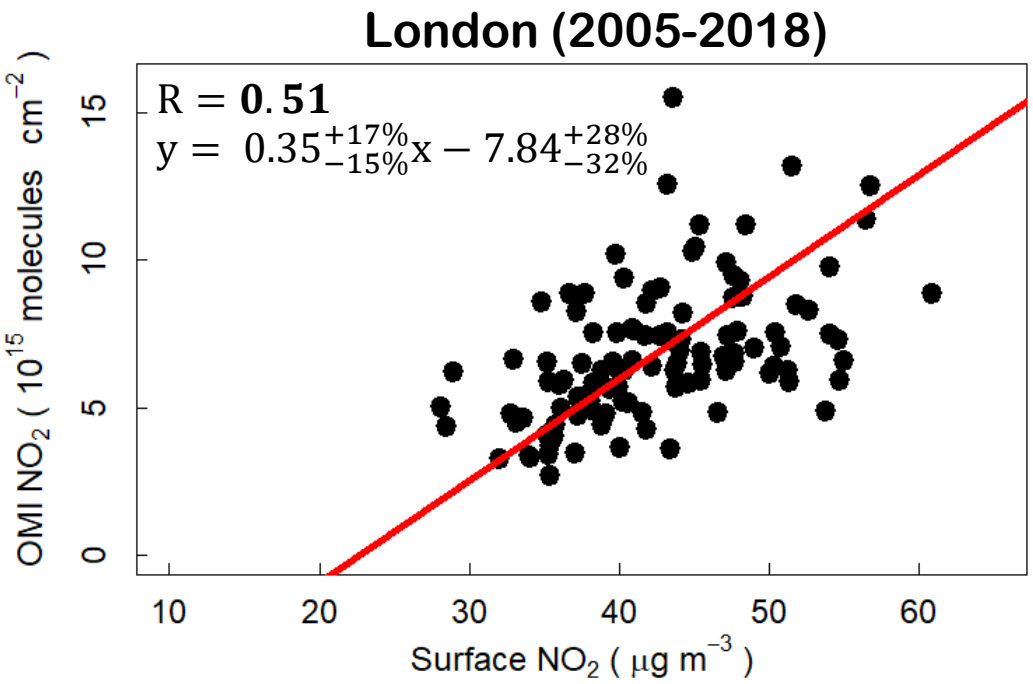
Air pollution is at the surface (~1-2 km)



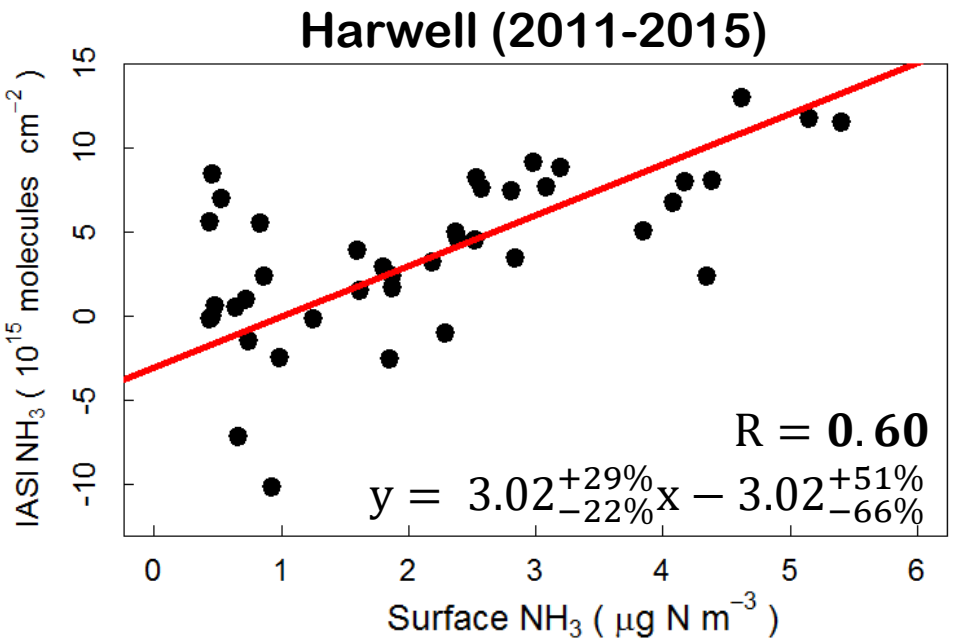

Column is sensitive to changes in surface concentration

# And conduct careful assessment with surface monitors (where available)

Satellite versus surface $NO_2$ in London



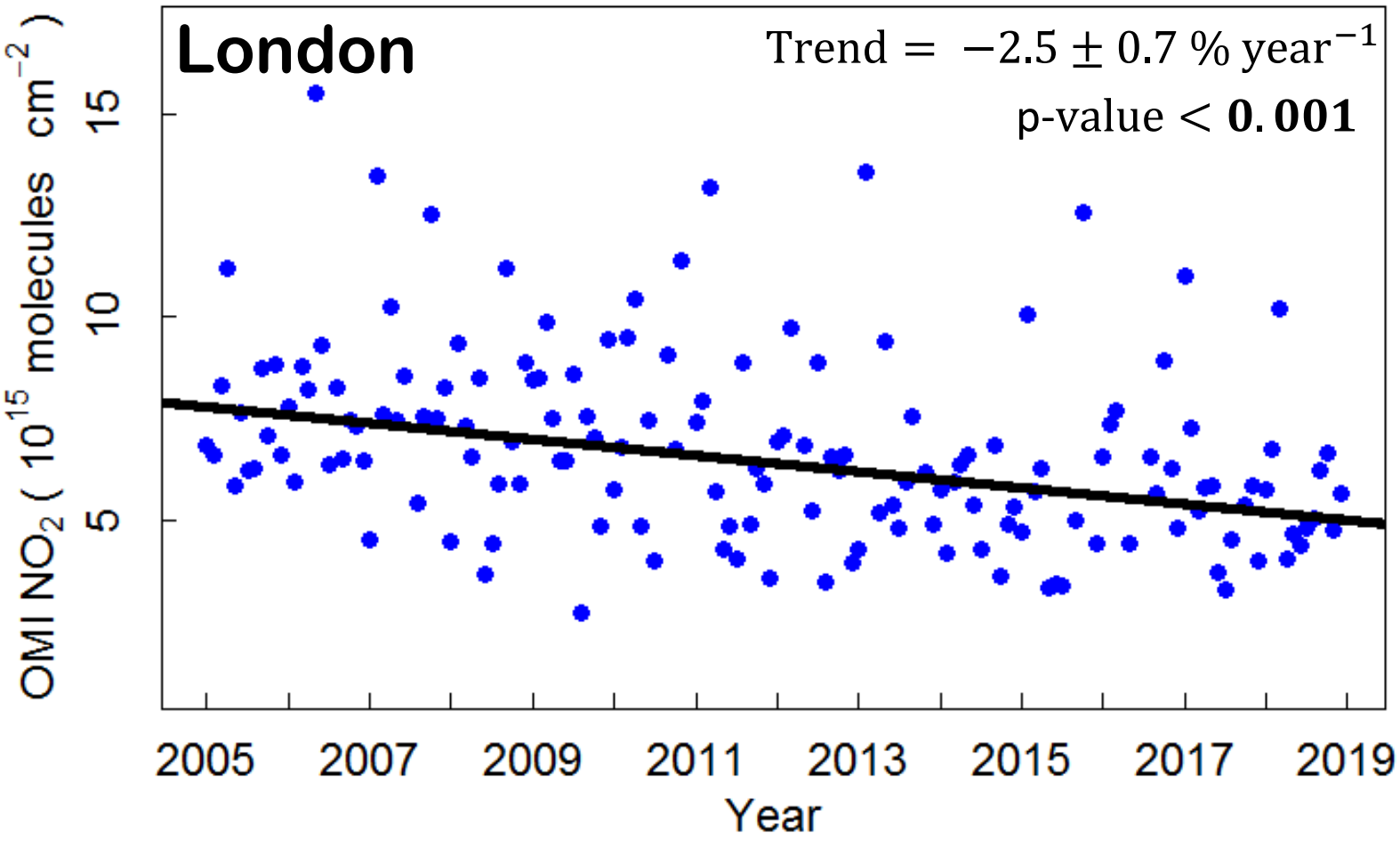

Satellite versus surface $NH_3$ in Harwell




Points are monthly averages

Pearson's correlation coefficient (R-value) indicates consistency

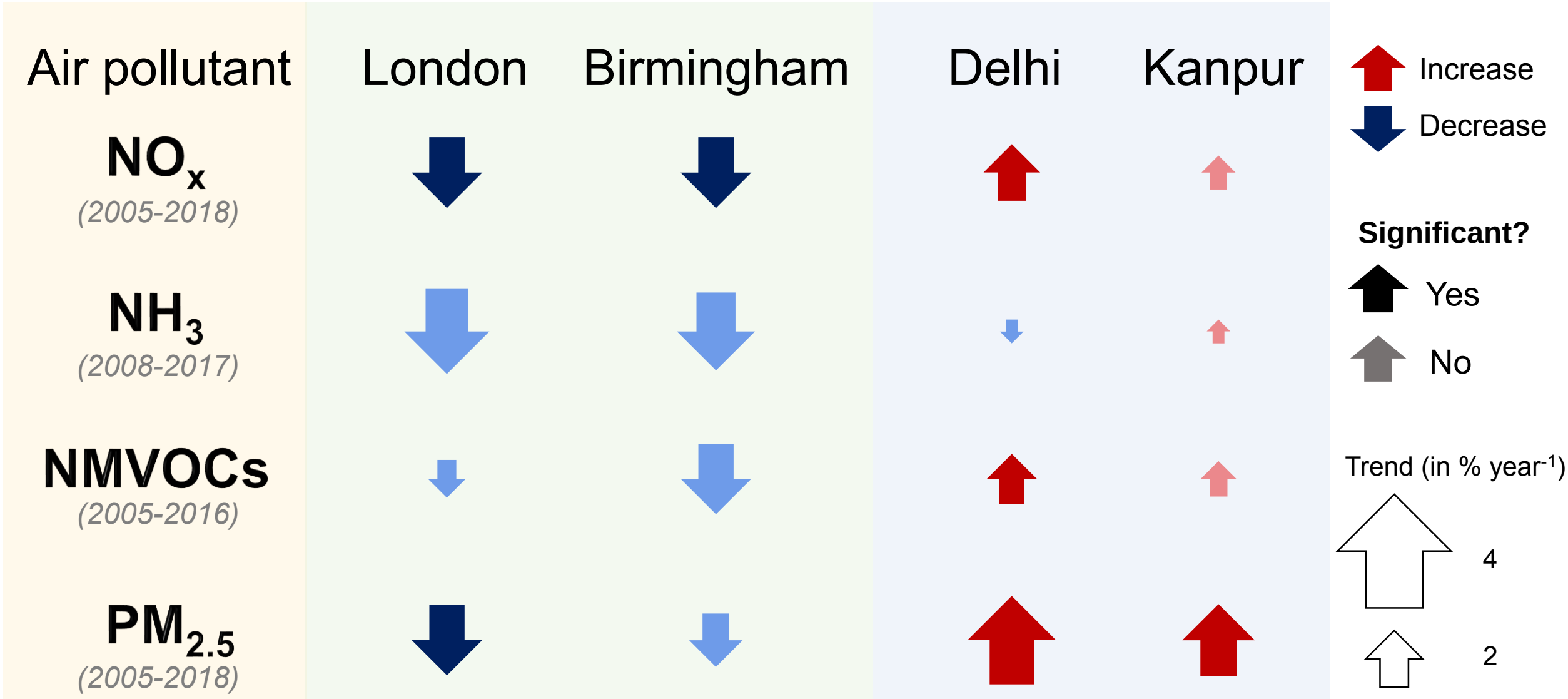
# We use robust statistics to derive trends




$NO_2$ ($NO_x$) over London decreased by **35 %** from 2005 to 2018

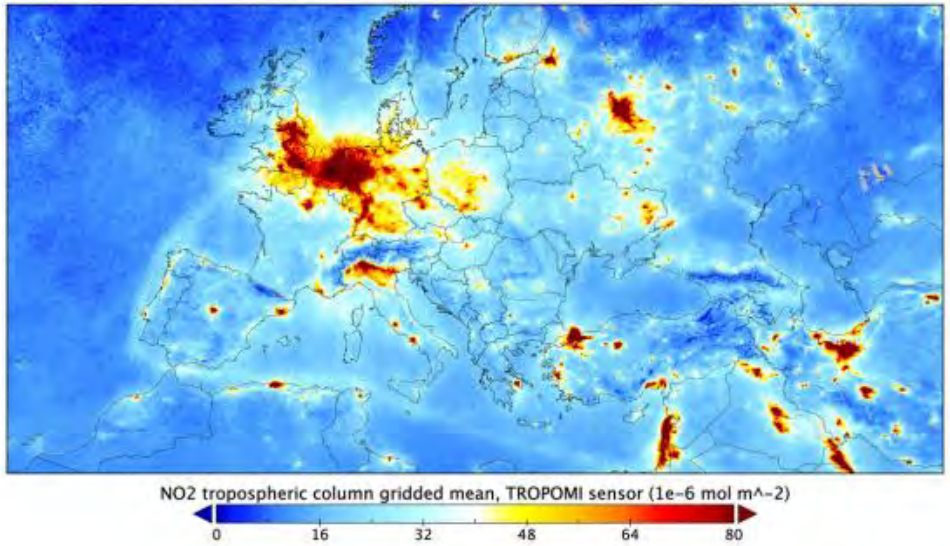
# Air pollution control measures are working in the UK

# While air quality has been deteriorating over time in India



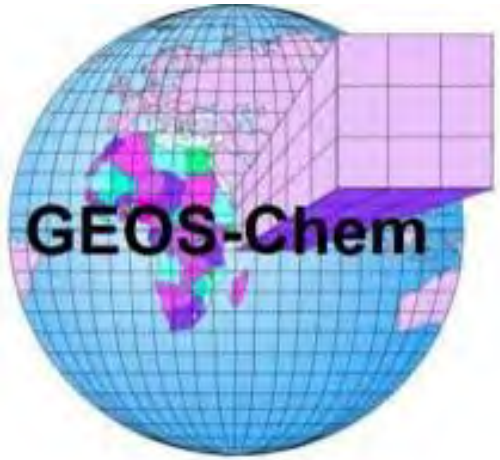
# Next steps

## High spatial resolution satellite data



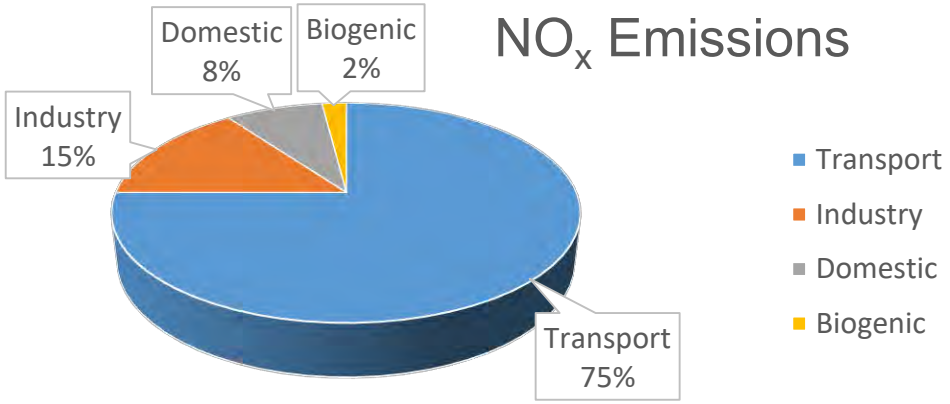

TROPOMI $NO_2$ for April 2018 [Geffen et al., 2019]

## Global 3D Chemical Transport Model




Interpret data using model to understand drivers of trends and inter-annual variability in air pollutants

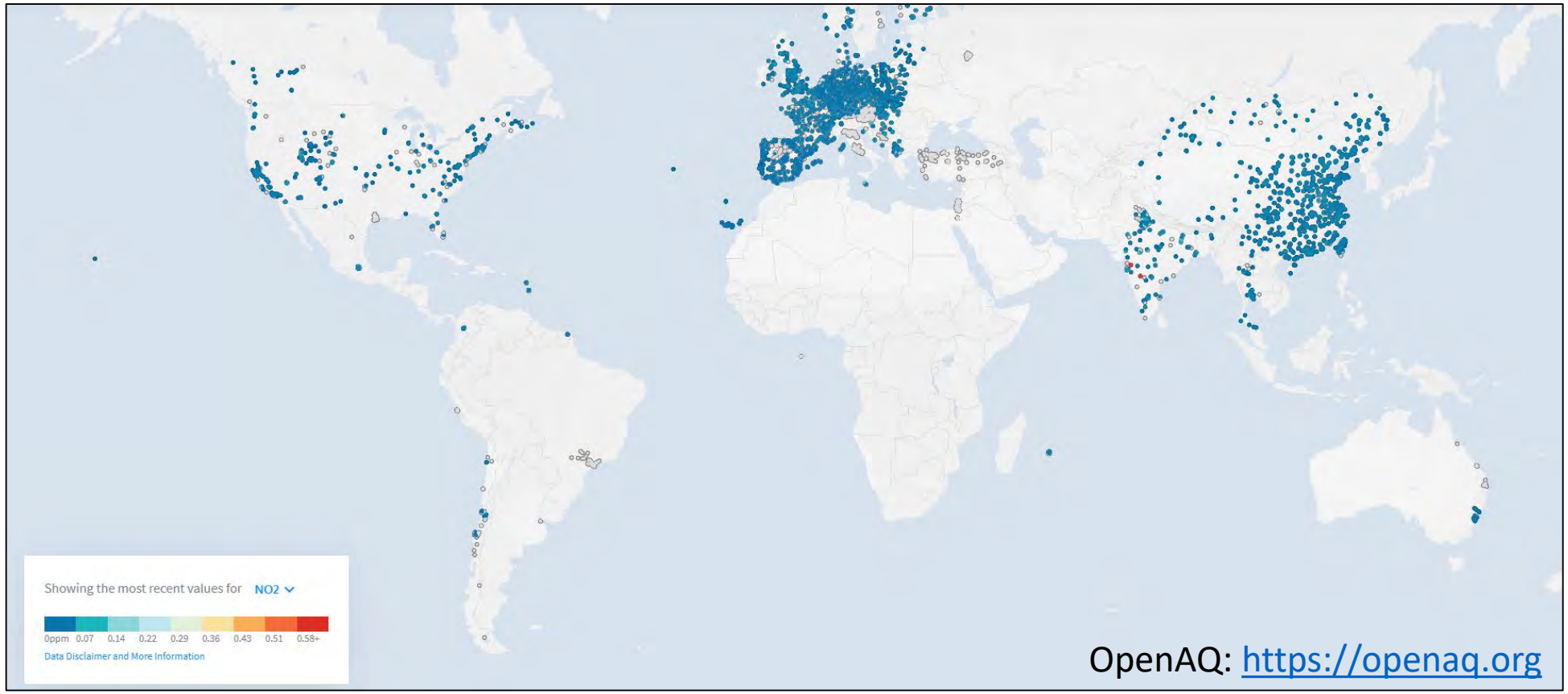
## Compute emission inventory



# A global problem

## No routine monitoring of air pollutants in many parts of the world

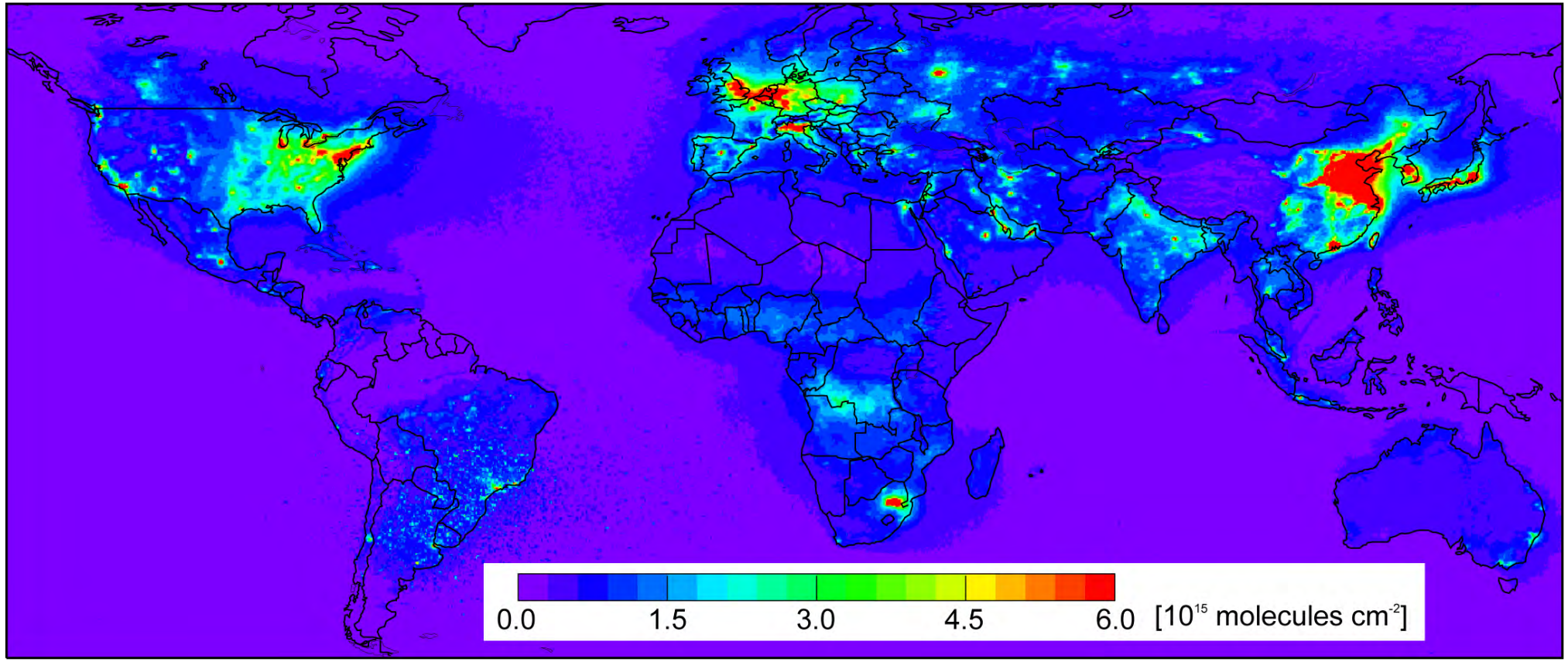
Publicly available $NO_2$ data for 14th October, 2019



# A scalable solution

## The algorithms that we have developed can be applied to any city in the world

Global annual average $NO_2$ concentrations observed with OMI for 2005-2006



# Acknowledgements



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Thank you


and everyone for your attention!!!