

# Long-term trends in city-wide air quality: A space-based perspective

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BEAR Conference

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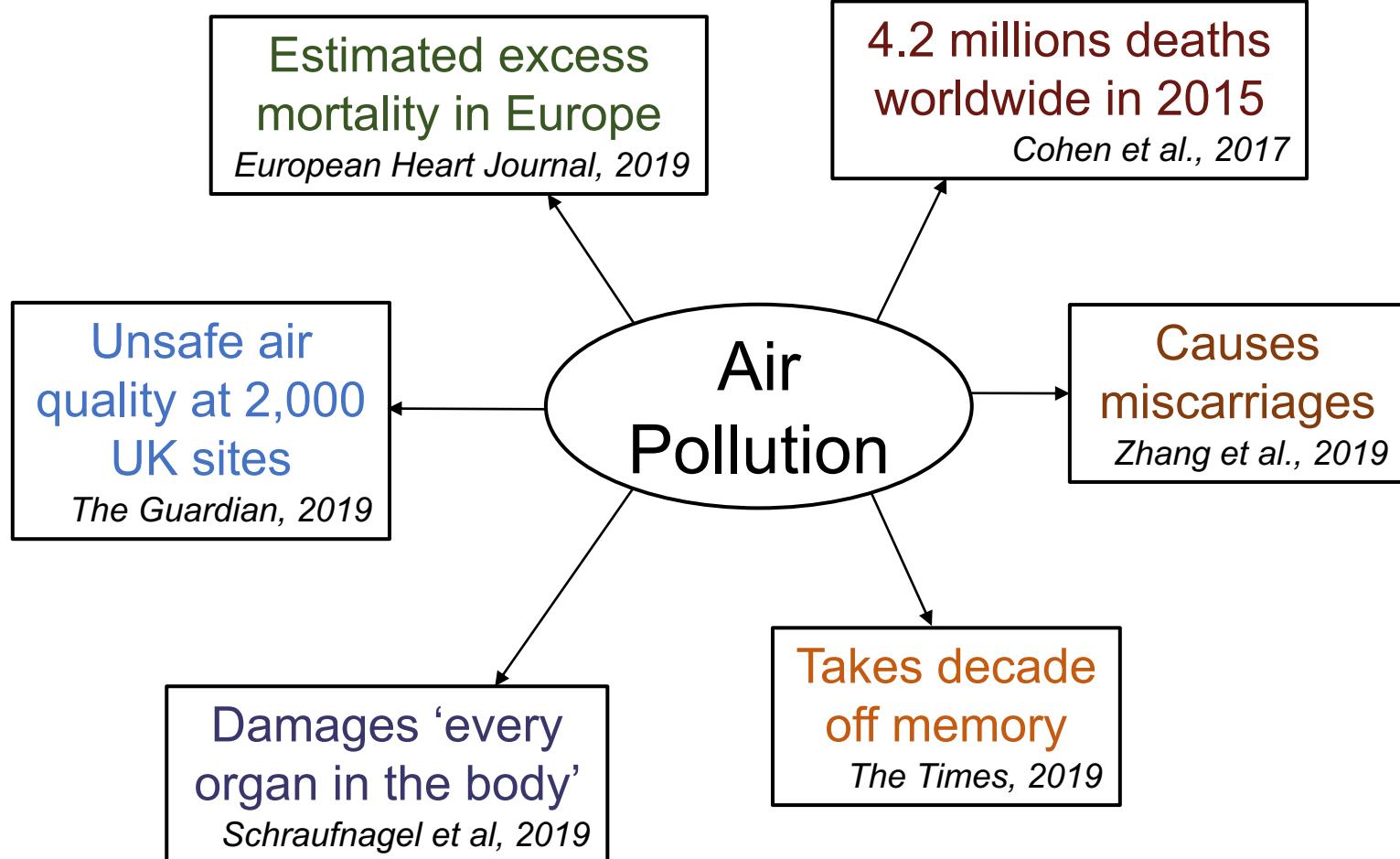


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# The Problem

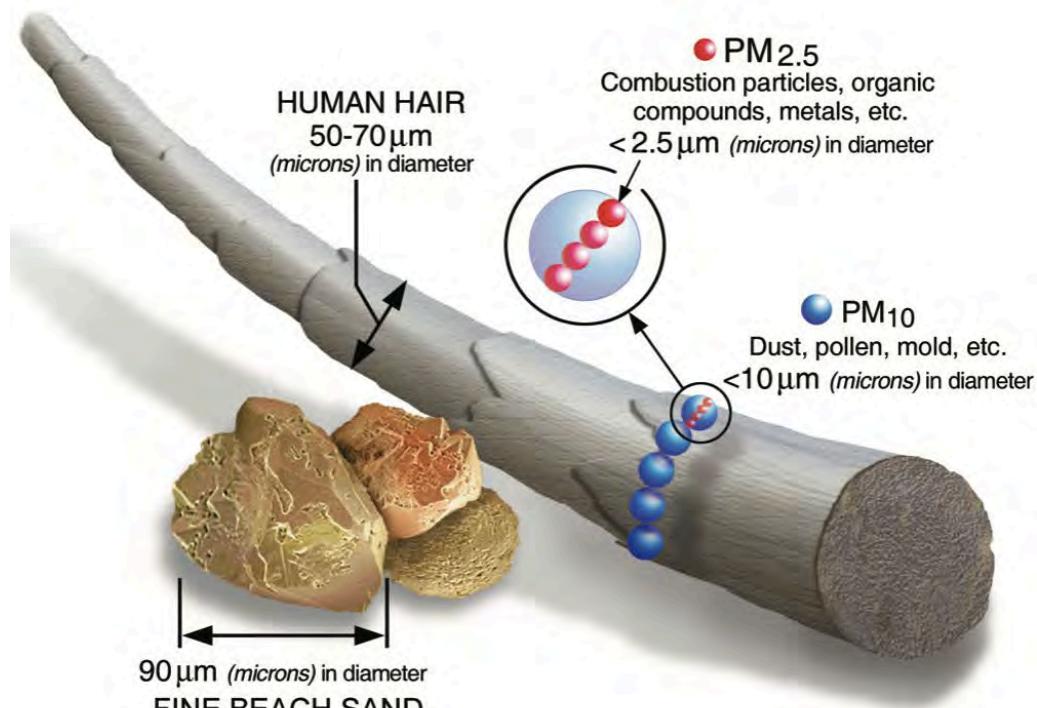


Gurgaon, India (3<sup>rd</sup> Nov'16, 1.30 pm)

What's common??? Particulate Matter (PM) & Nitrogen dioxide (NO<sub>2</sub>)

# The Problem

## Particulate Matter (PM)



Source – US EPA

## Nitrogen dioxide (NO<sub>2</sub>)



Source – newatlas.com

PM<sub>2.5</sub> ~79%

25  $\mu\text{g m}^{-3}$



Emissions reductions\* (1970-2017)

Annual mean compliance limits\*\*

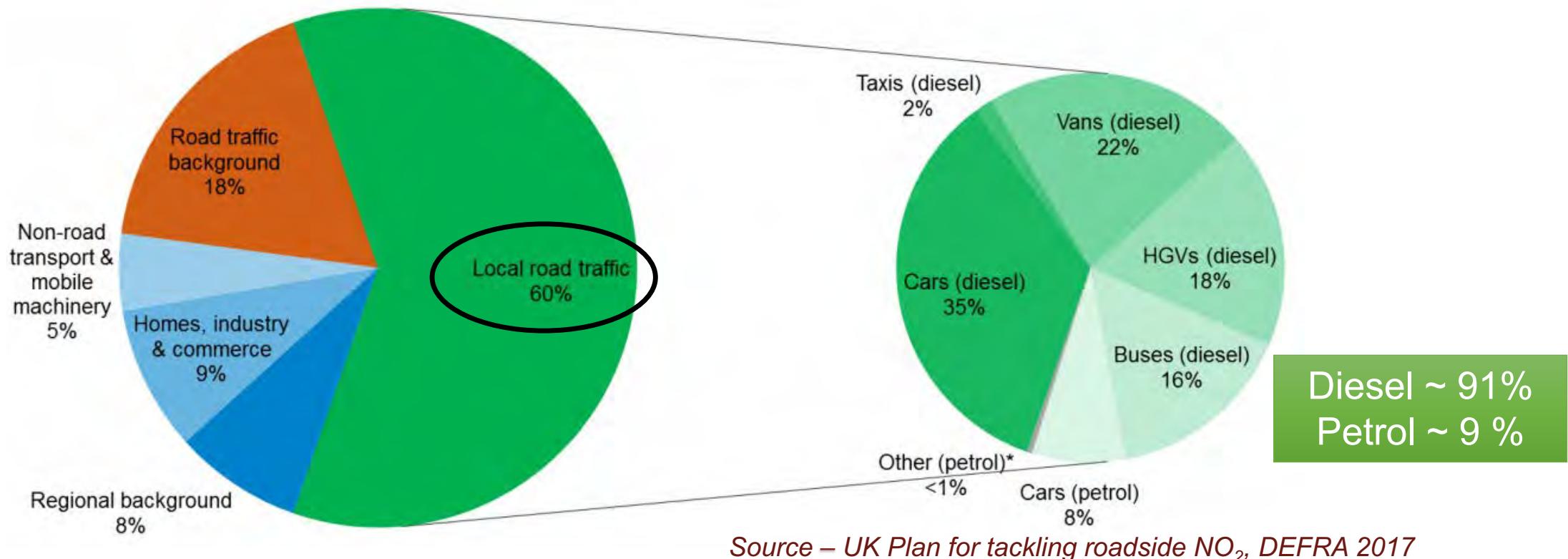
NO<sub>x</sub> ~72%

40  $\mu\text{g m}^{-3}$



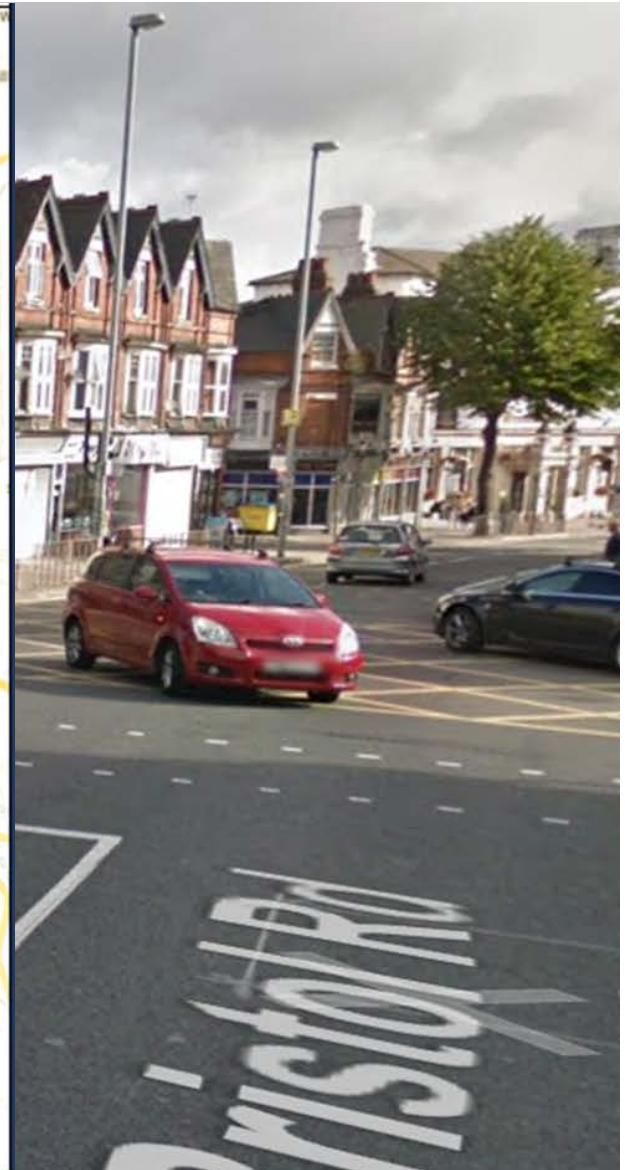
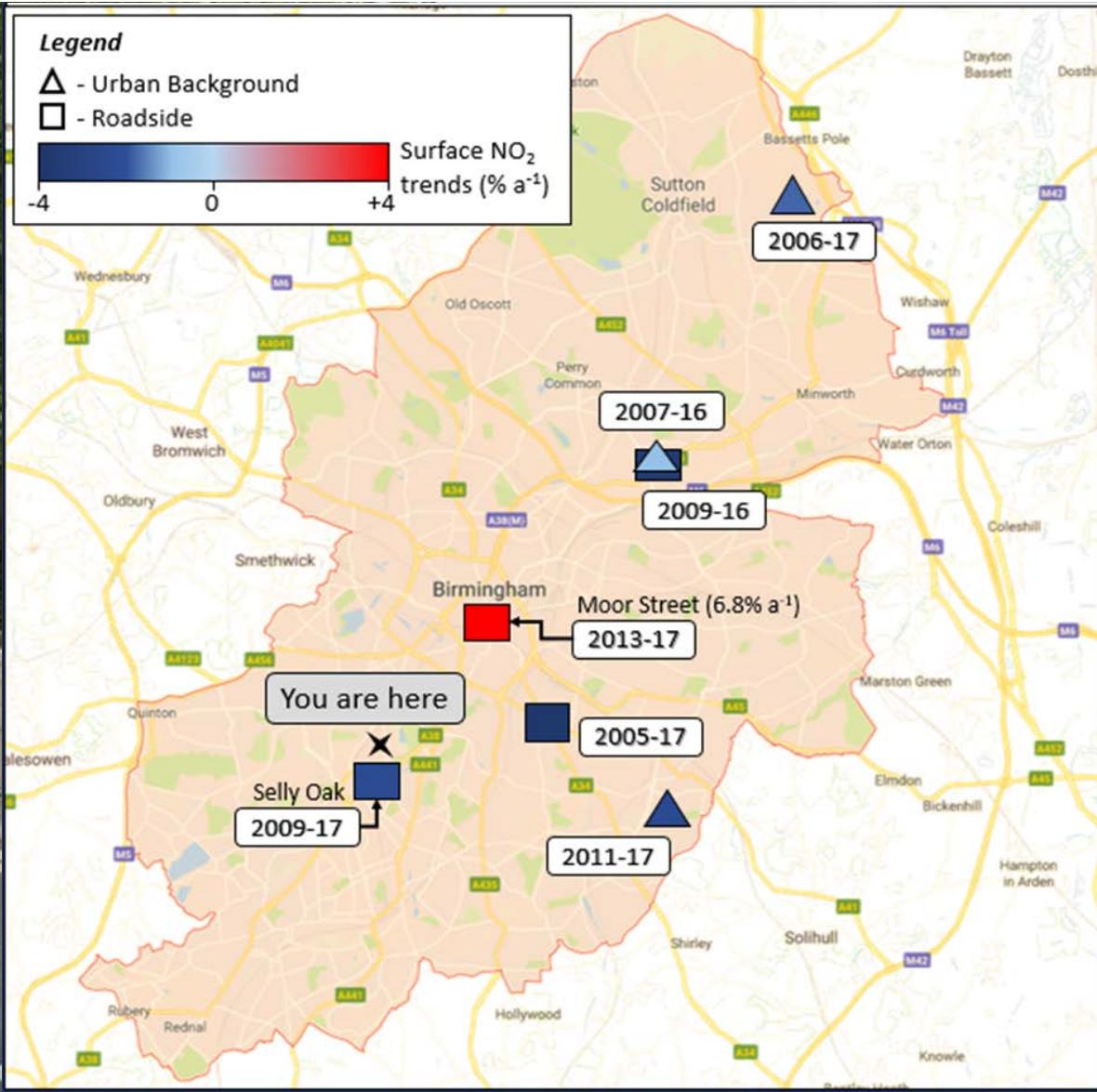
# The Problem

Sources of UK roadside NO<sub>2</sub> for 2015



How do we know if NO<sub>2</sub> is going down?

# The Current Approach

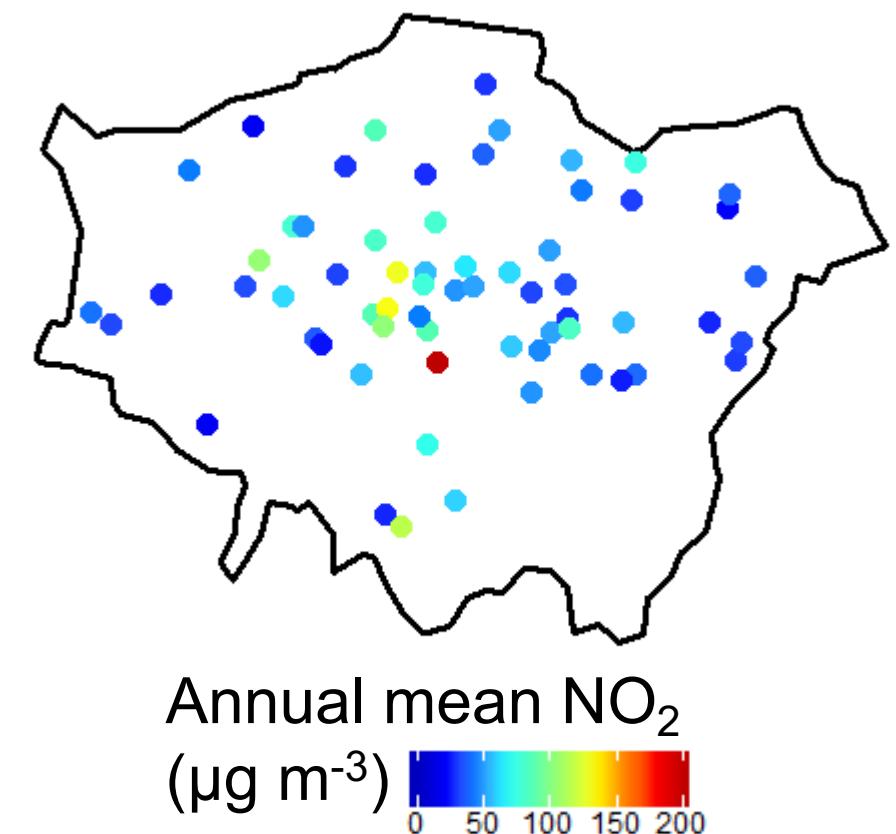


# The Current Approach

Surface monitoring networks  
have their limitations

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

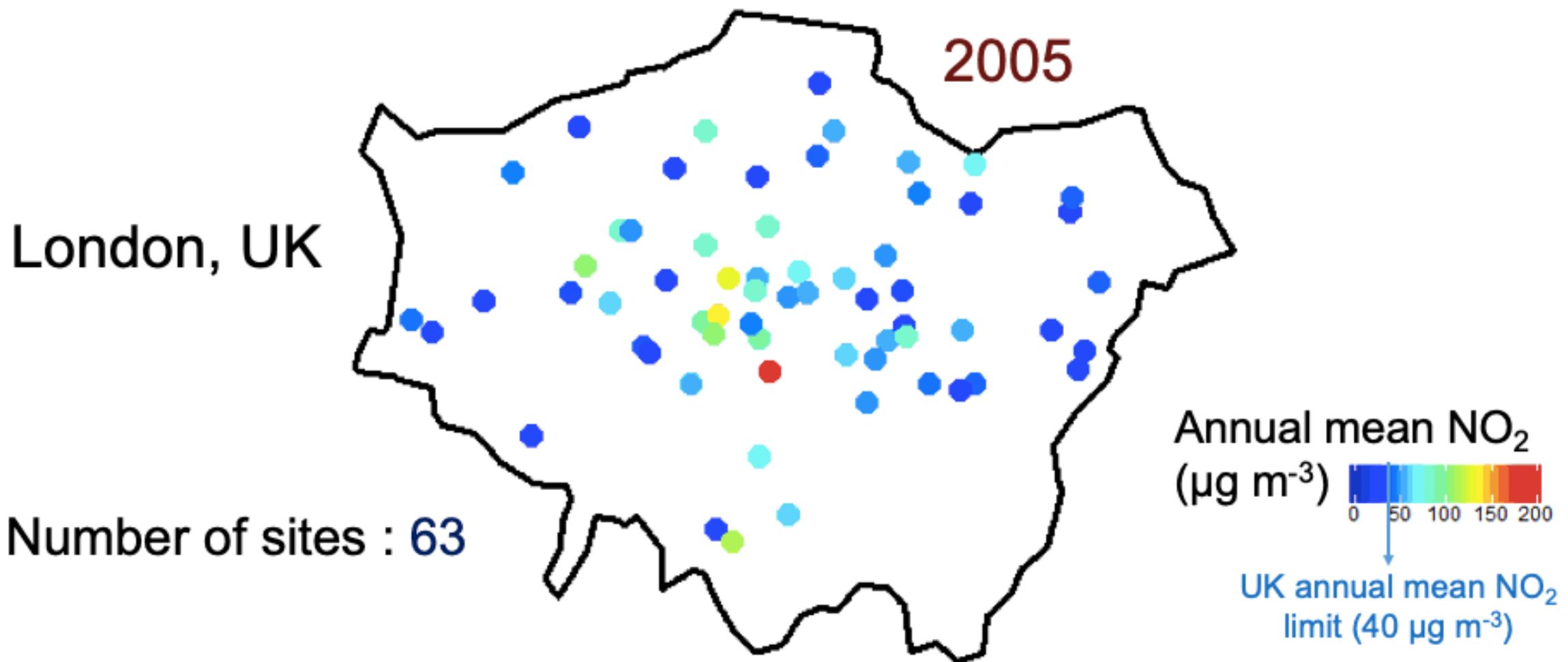
London, UK      2005



Data from *London Air Quality Network (LAQN)*

# The Current Approach

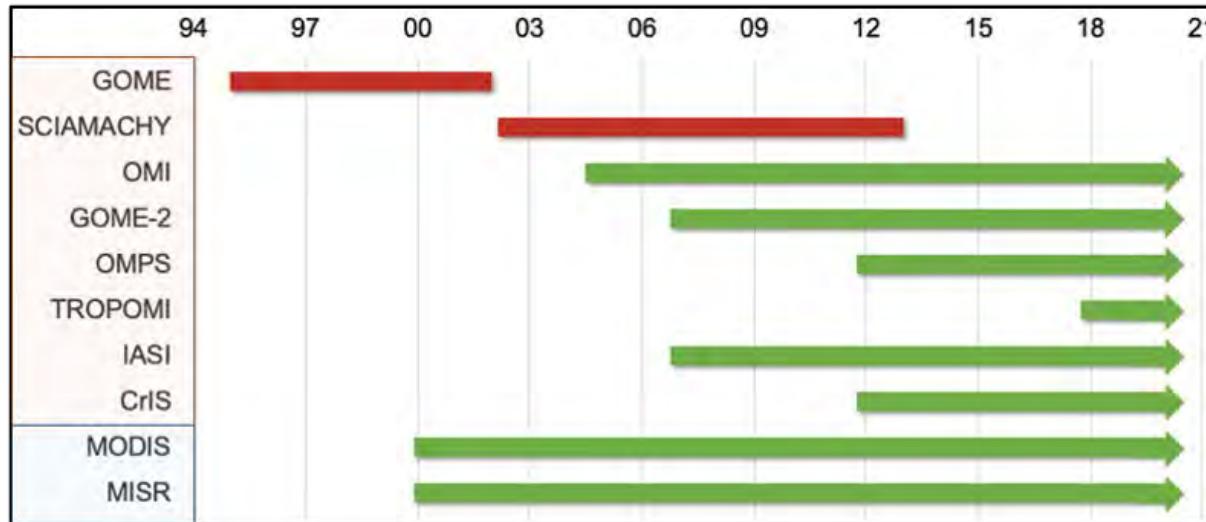
- ☐ Inconsistent (sites come and go over time)



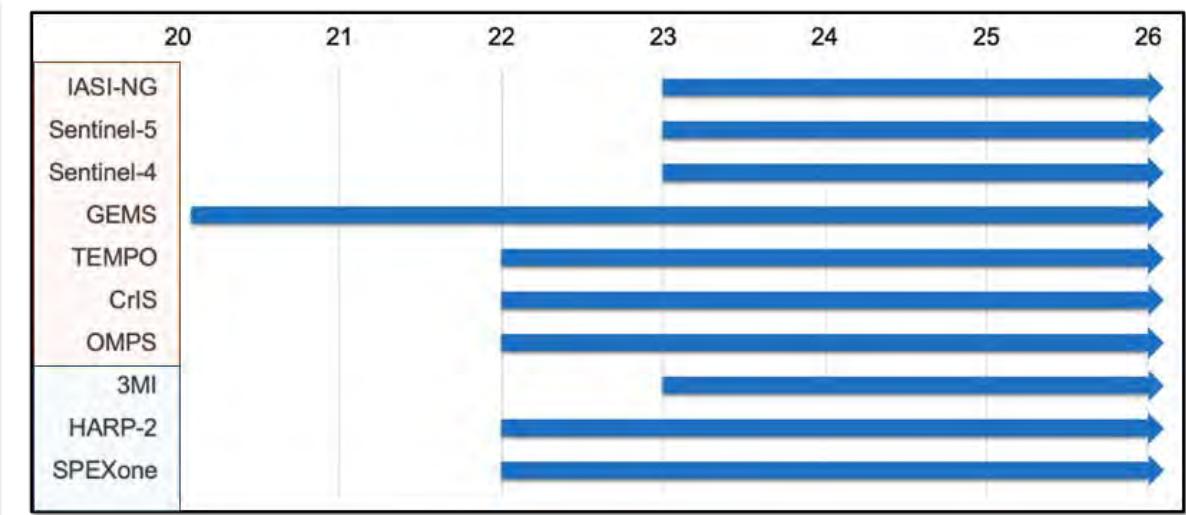
# The Solution

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

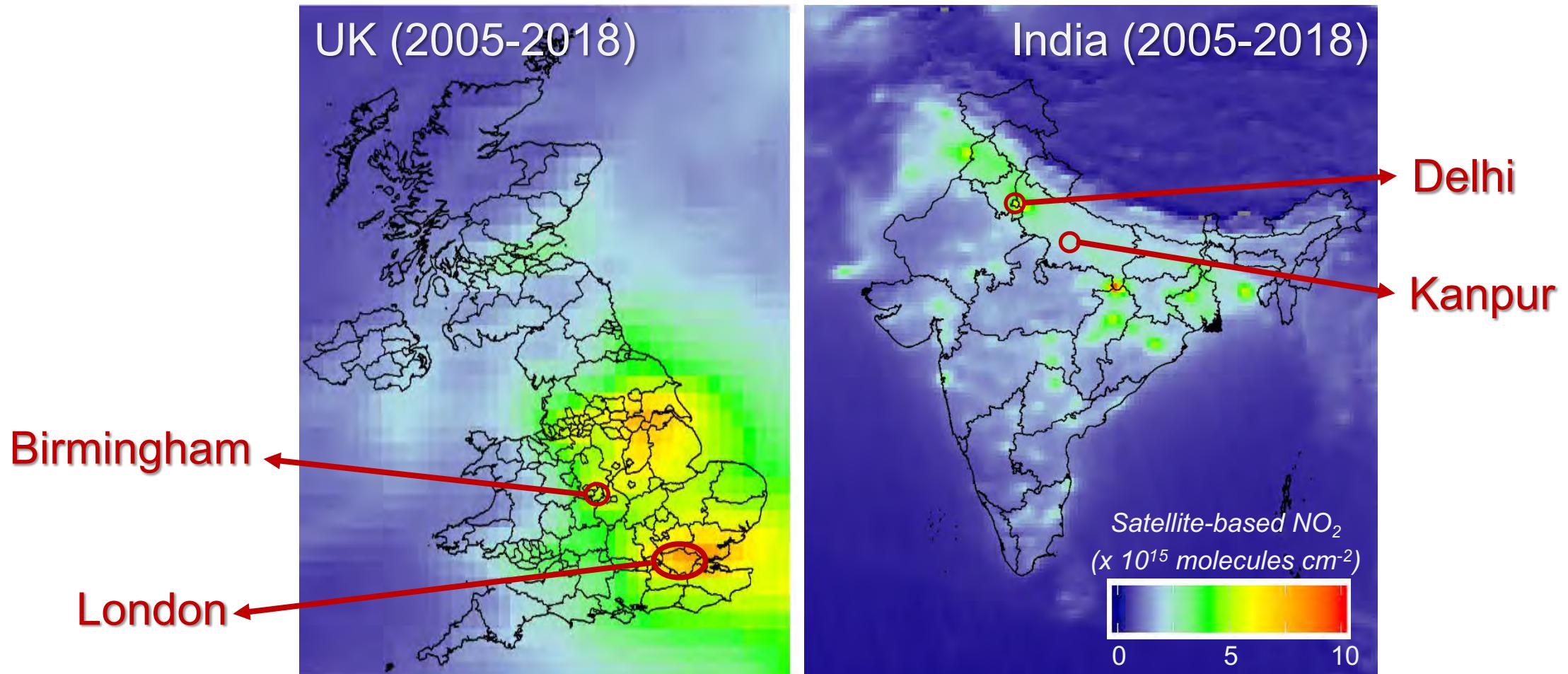
Completed

On-going

Future

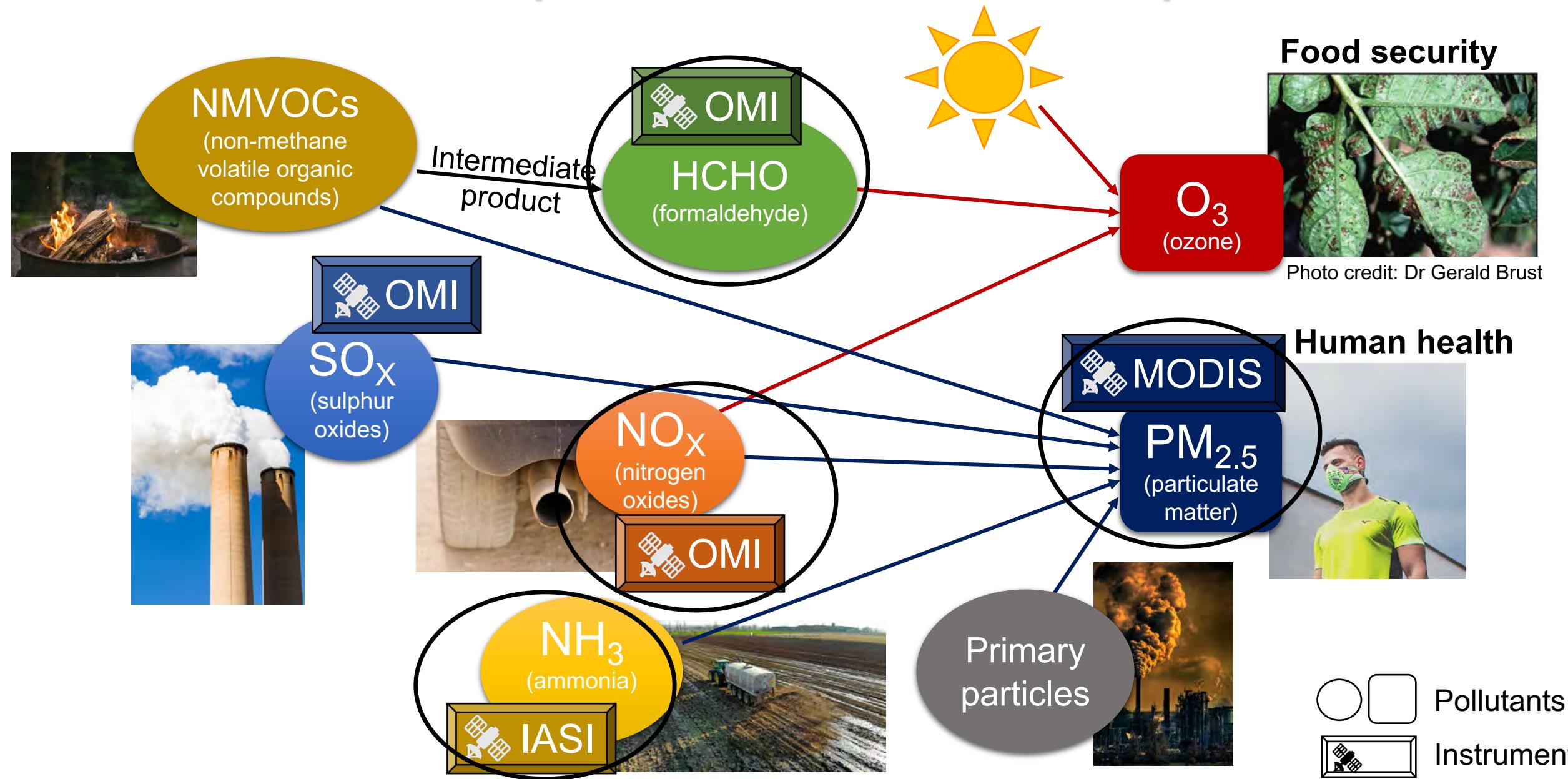
# Space-based instruments provide extensive data coverage

We develop our approach focusing on 4 dynamic cities



\* Maps on different scales

# Satellites help monitor these air pollutants



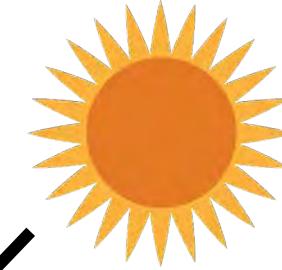
# Satellite columns reflect changes in surface pollution



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

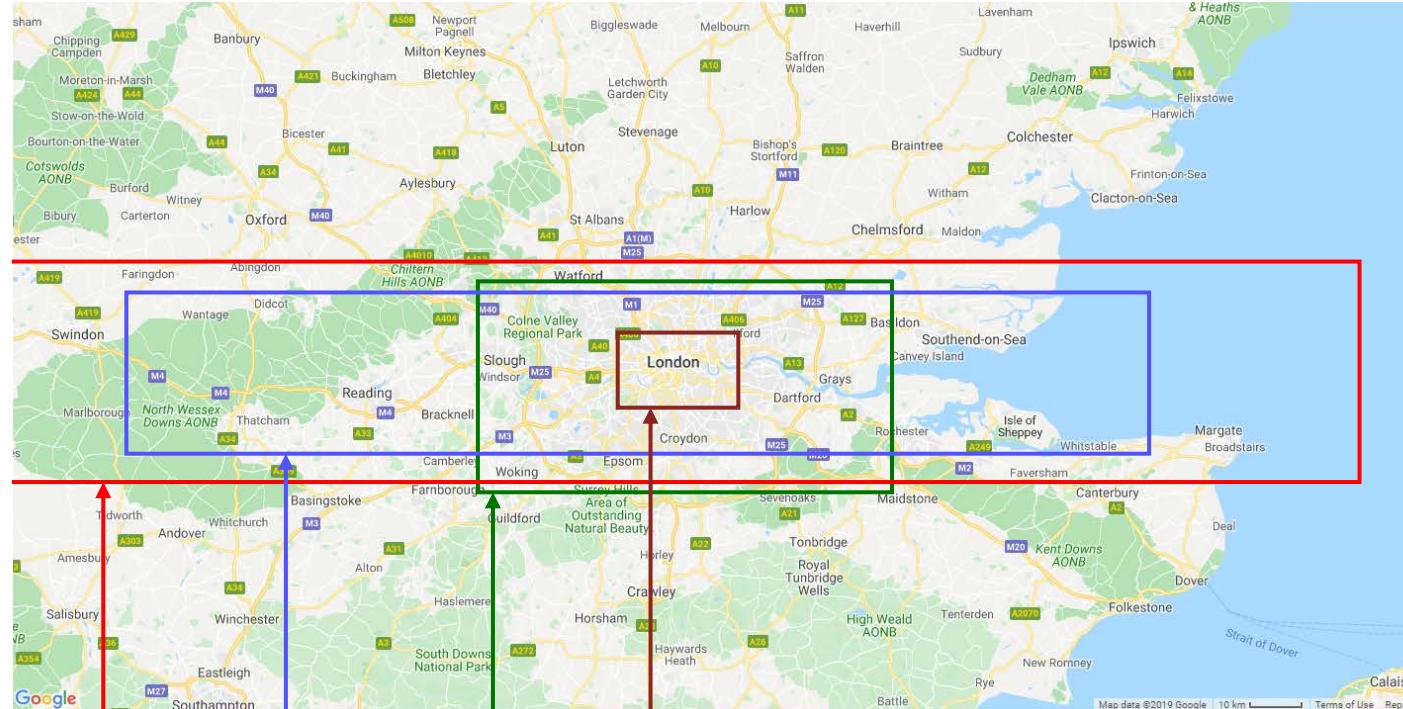


Satellite measures  
whole atmospheric  
column (>10 km)



Column is sensitive to  
changes in surface  
concentration

# Measurements are at coarse resolution so we sample the whole city



OMI (24 km x 13 km, 2004-present)

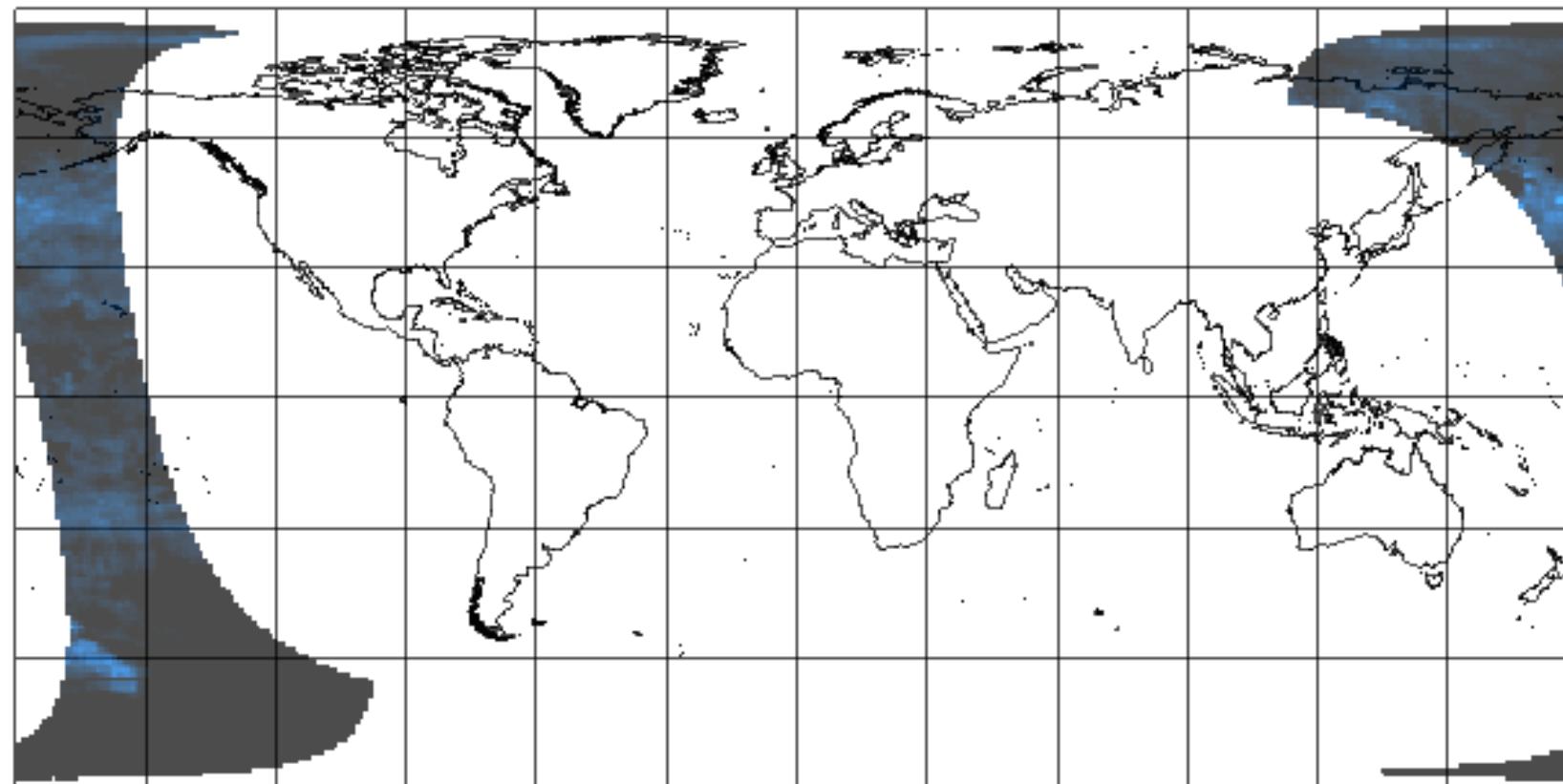
GOME-2 (80 km x 40 km, 2007-present)

SCIAMACHY (200 km x 30 km, 2002-2012)

GOME (320 km x 40 km, 1995-2001)

# OMI achieves global coverage in a day

OMI overpass time : 13h30 local time



tropospheric NO<sub>2</sub> column number density (Pmolec/cm<sup>2</sup>)

0

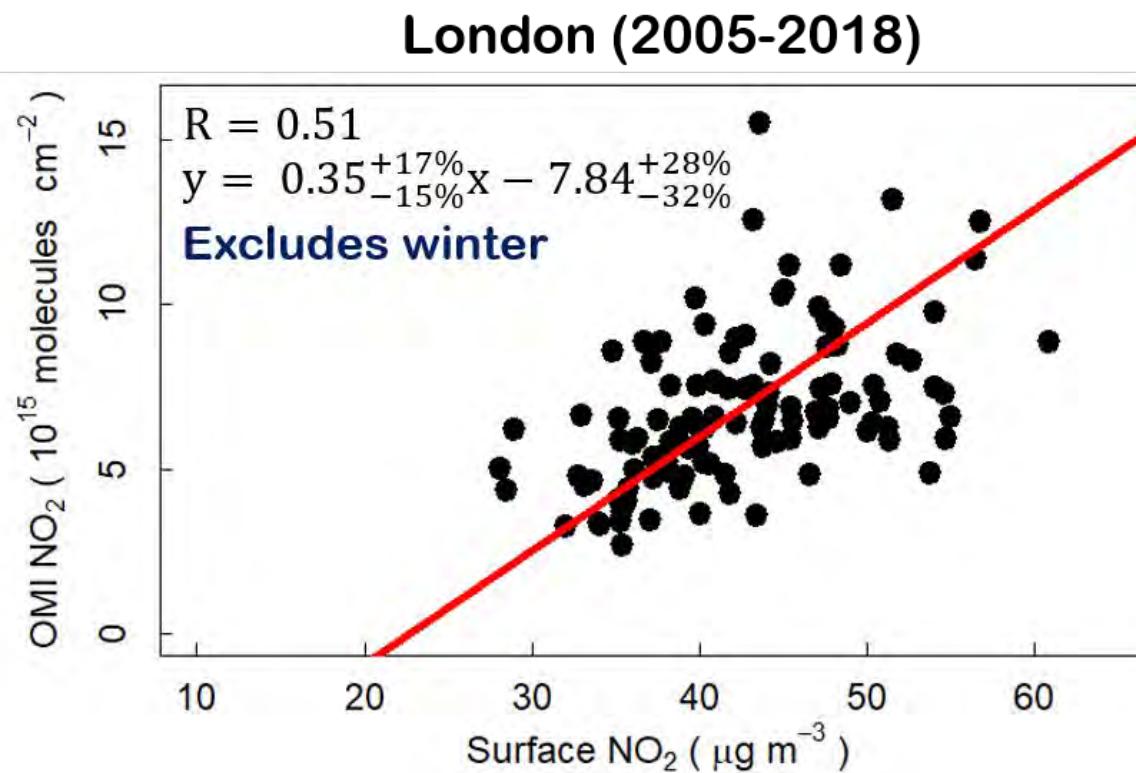
6



OMI NO<sub>2</sub> snapshots for each orbit (22<sup>nd</sup> Sep'19)

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

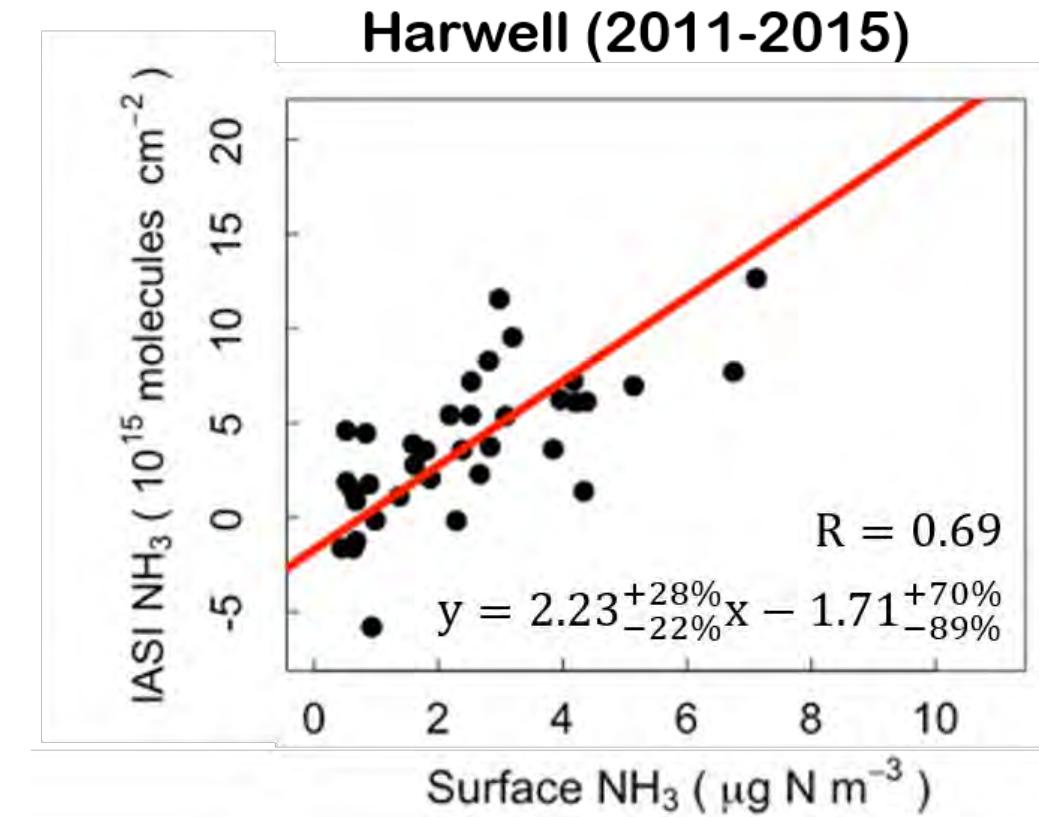
Satellite versus surface NO<sub>2</sub> in London



Points are monthly averages

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

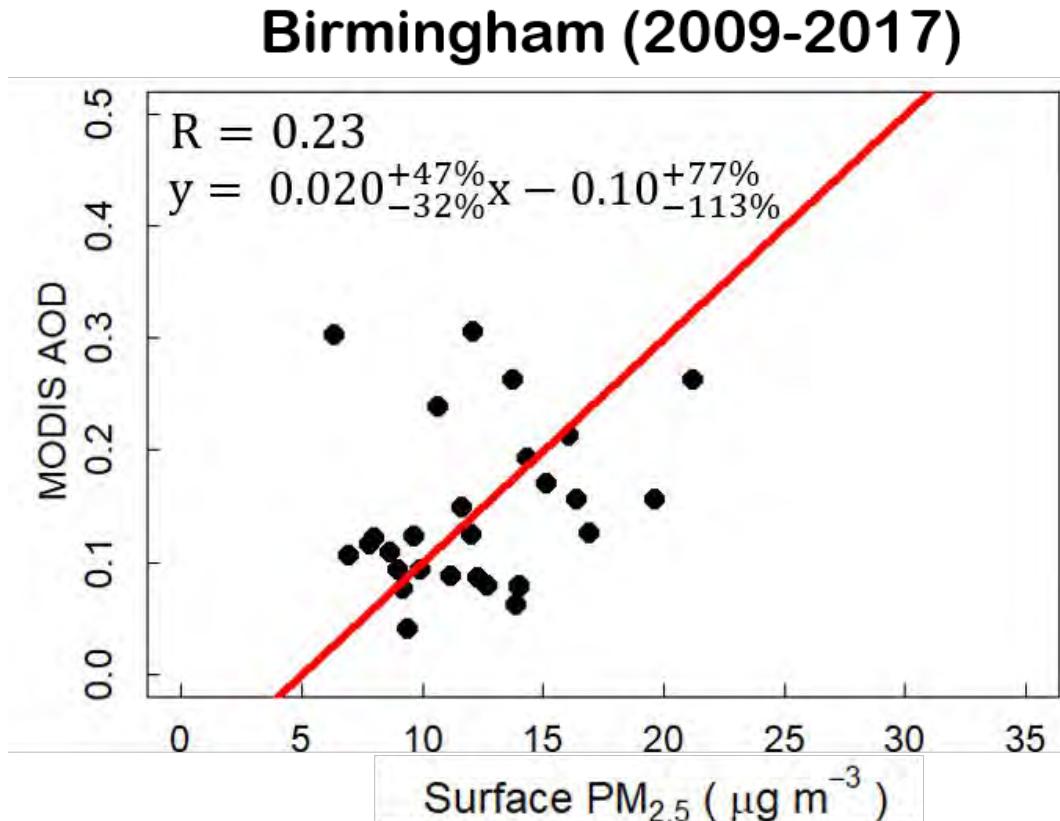
Satellite versus surface NH<sub>3</sub> in Harwell



[ Vohra et al., ACPD, in review ]

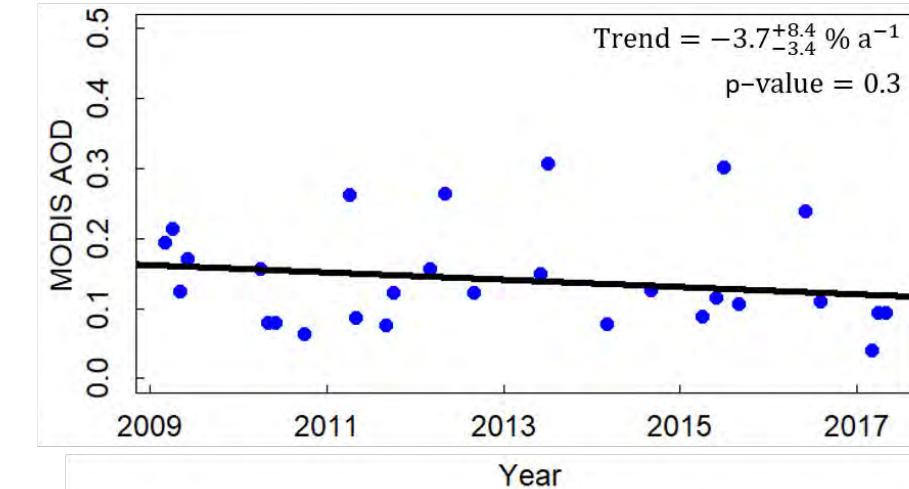
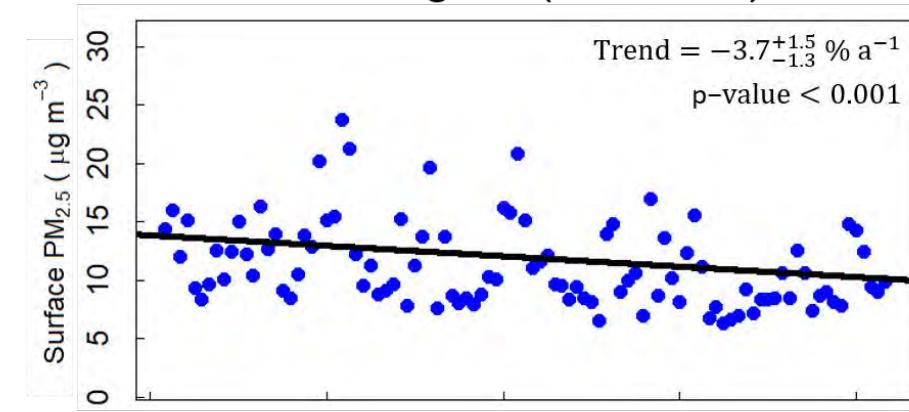
# We conduct careful assessment with surface monitors (where available)

Satellite versus surface PM<sub>2.5</sub> in Birmingham



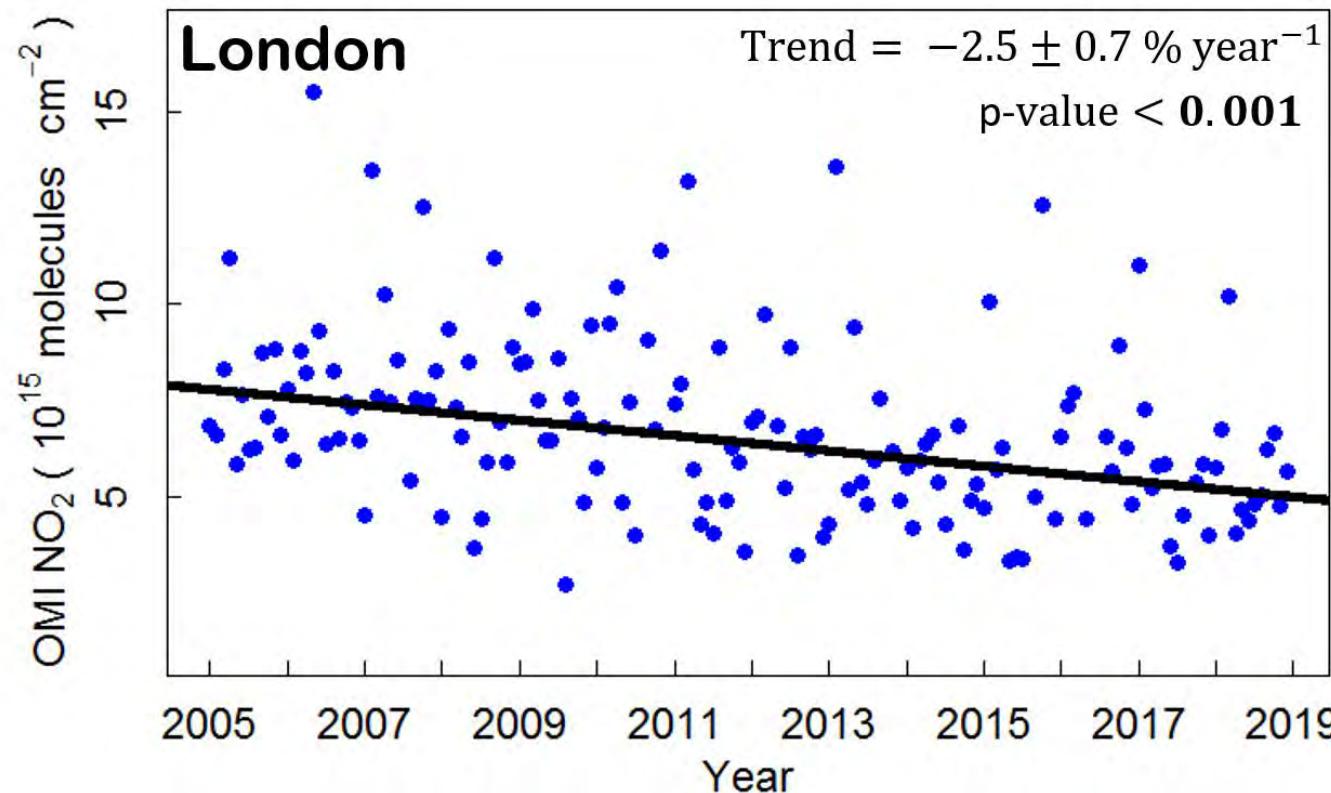
Similar results were obtained for London

Birmingham (2009-2017)



# And apply trend analysis to long-term record of satellite observations

A) Trend in London NO<sub>2</sub>

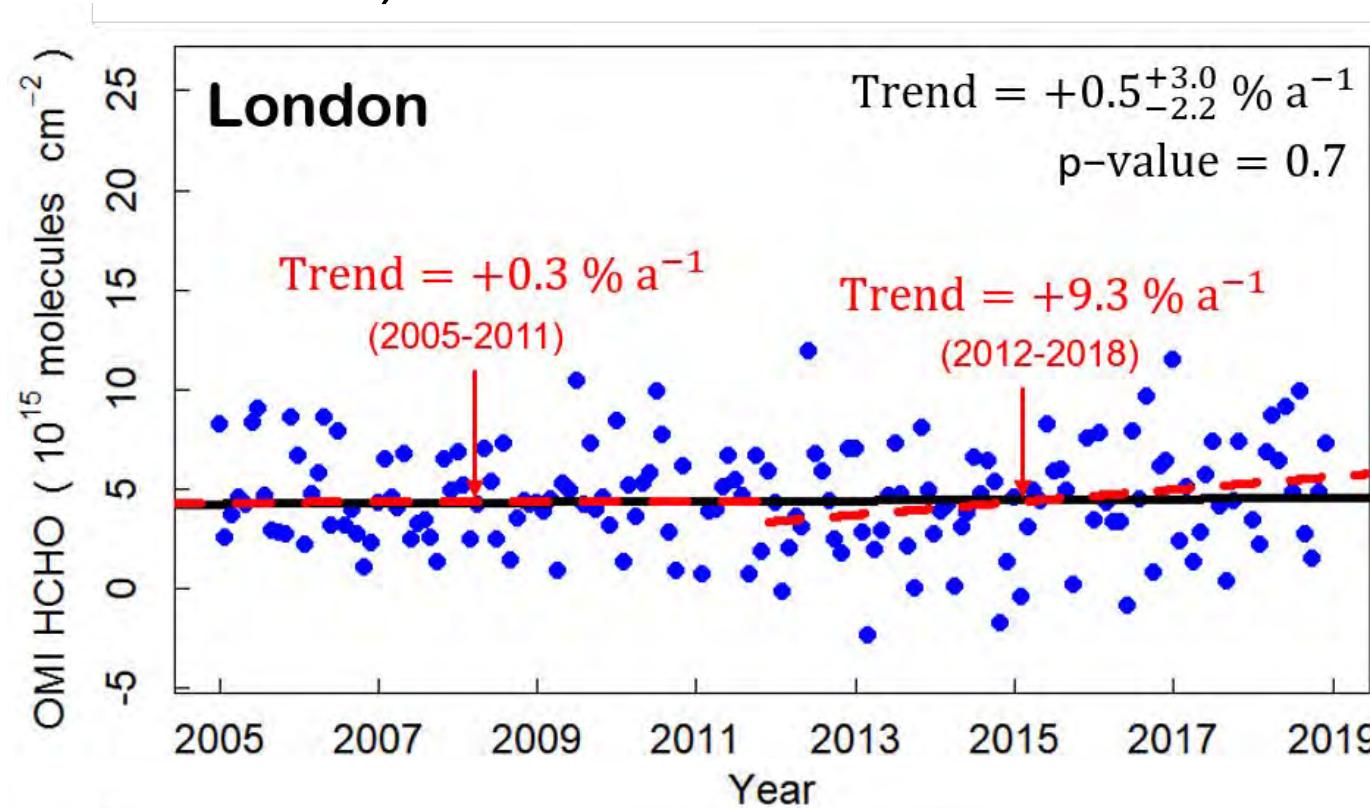


NO<sub>2</sub> over London decreased by 35 % from 2005 to 2018



# And apply trend analysis to long-term record of satellite observations

B) Trend in London NMVOCs



Reactive NMVOCs have increased by over 65 % in London since 2012



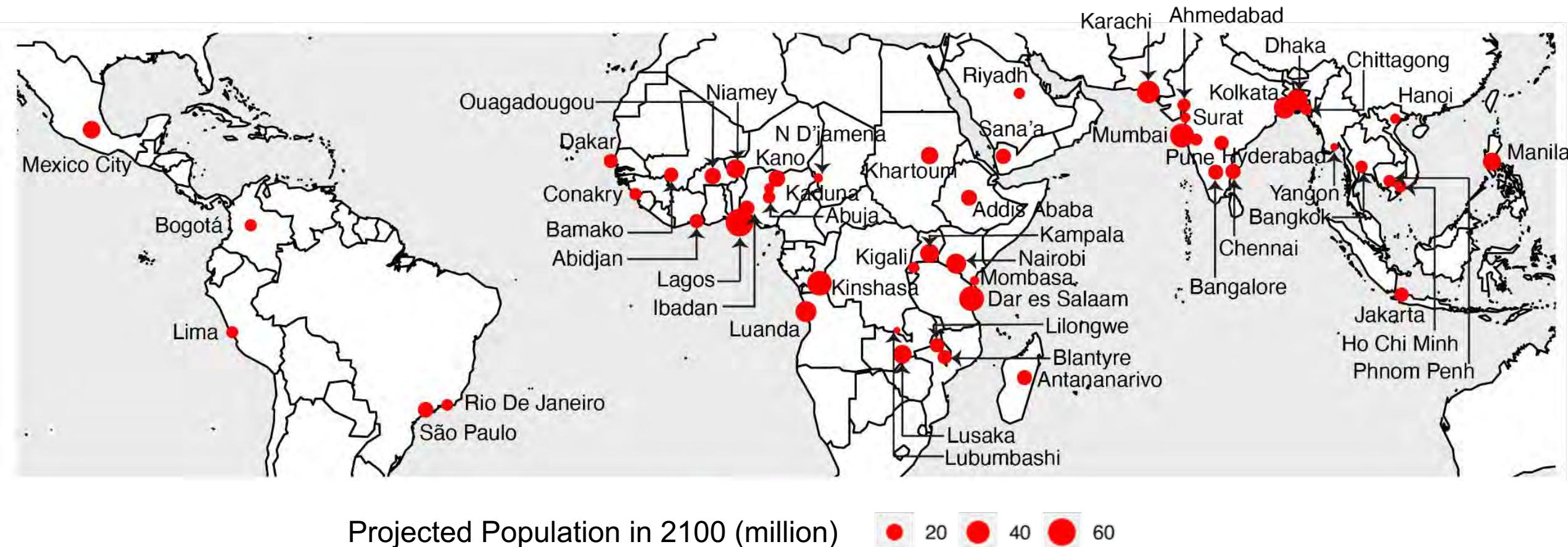
# Long-term air pollutant trends for cities in the UK and India

(Arrow colour, intensity, and size indicate trend direction, significance and magnitude respectively)



# Tropics are the next frontier in air pollution

51 cities within the tropics will be megacities by 2100 [Hoornweg & Pope, 2016 ]



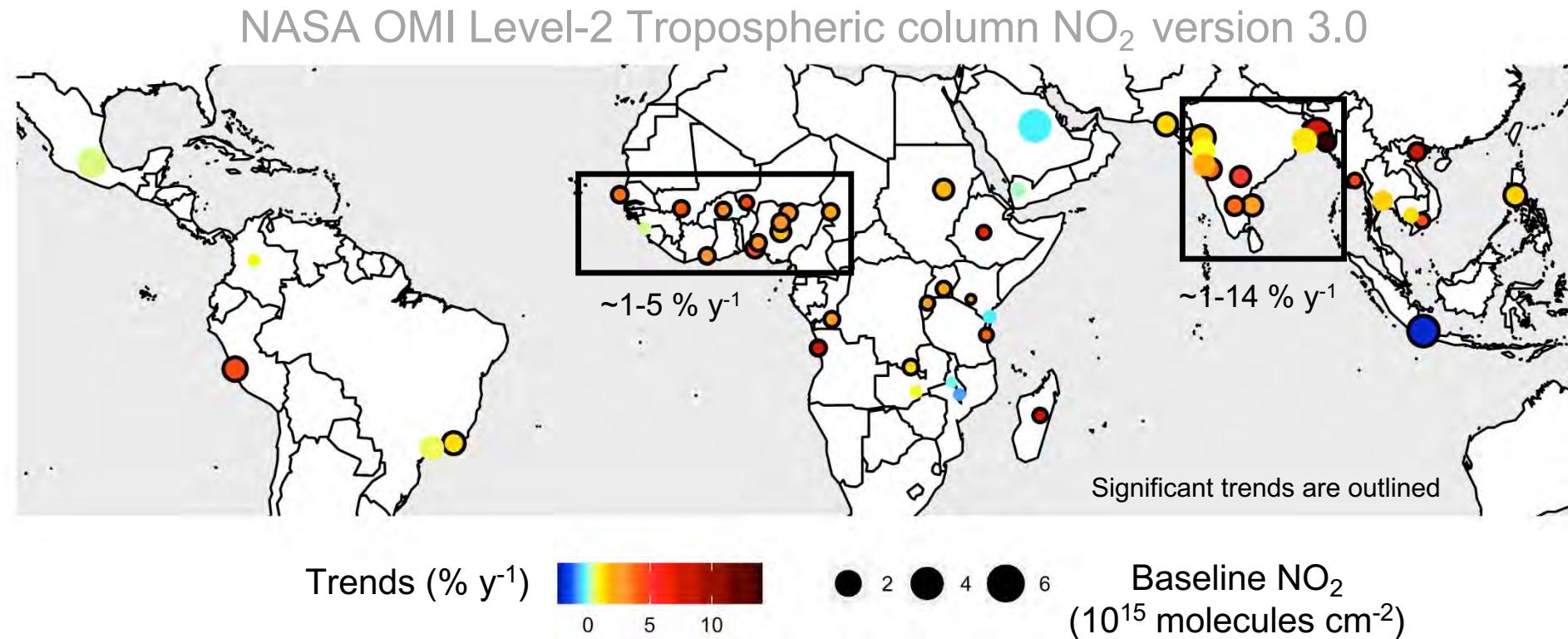
# Tropics are the next frontier in air pollution

Currently, limited routine monitoring across the tropics



# Megacity OMI NO<sub>2</sub> trends for 2005-2018

NO<sub>2</sub> is a precursor of tropospheric ozone, inorganic & organic nitrate aerosol



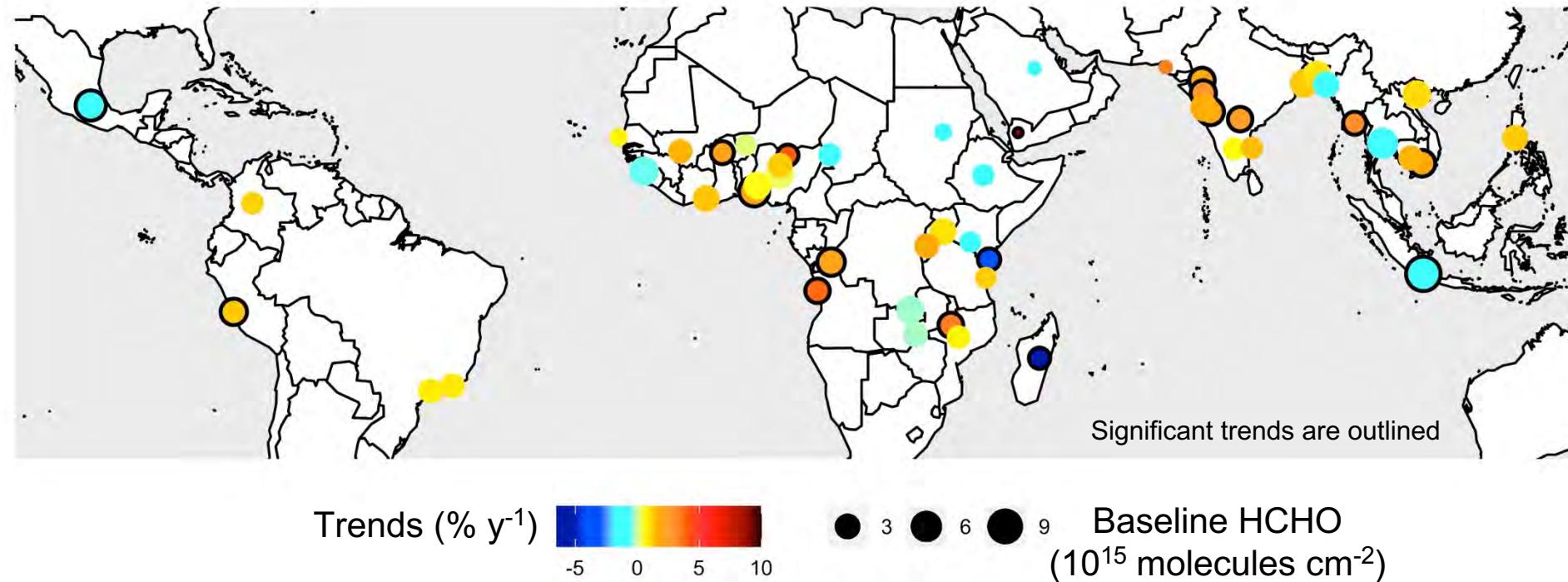
NO<sub>2</sub> has increased in 46 out of 51 cities

Year-round sources include anthropogenic sources like fossil fuel combustion, with large seasonal contributions from biomass burning

# Megacity OMI HCHO trends for 2005-2018

HCHO is a precursor of tropospheric ozone & carbon dioxide

QA4ECV OMI Level-2 Total column HCHO version 1.2



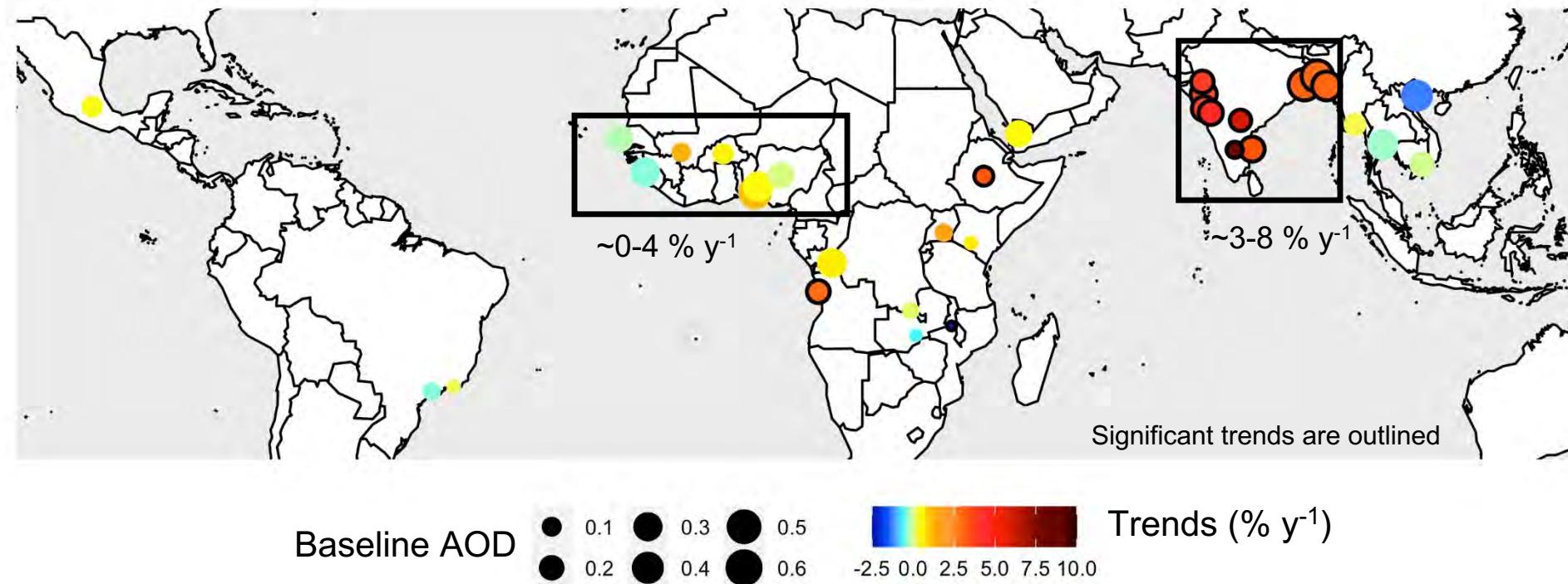
HCHO (reactive NMVOCs) has increased in 37 out of 51 cities

Year-round sources include anthropogenic sources (industry and domestic combustion) and biogenic sources, with seasonal contributions from biomass burning

# Megacity MODIS AOD trends for 2005-2018

Aerosols can be either absorbing or scattering

NASA MODIS Level-2 Dark Target AOD Collection 6.1



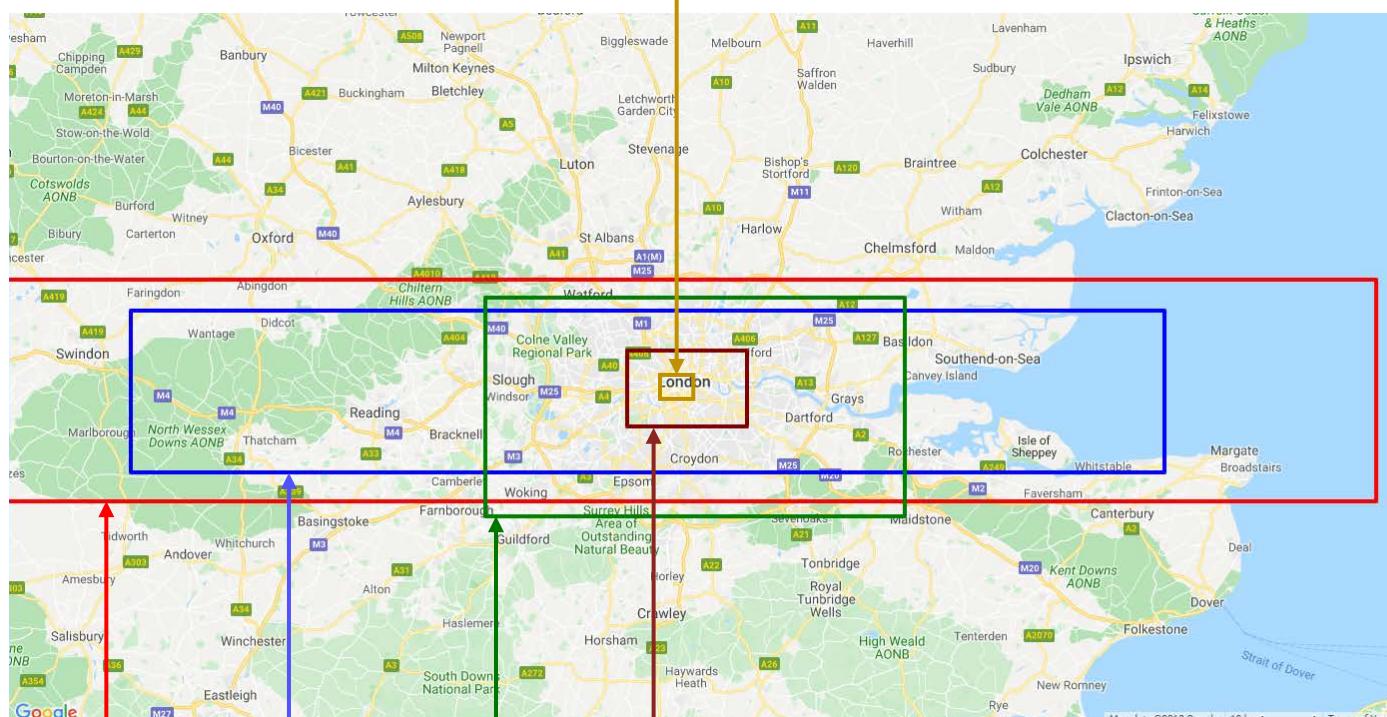
AOD has increased in 25 out of 33 cities

Dominant sources are many: secondary sources from  $\text{NO}_x$ ,  $\text{NH}_3$ , NMVOCs, primary sources of windblown dust, crop and trash burning, residential and open fires

# What's happening?

Next generation high spatial resolution space-based measurements

TROPOMI (5.5 km x 3.5 km, 2017-present)



OMI (24 km x 13 km, 2004-present)

GOME-2 (80 km x 40 km, 2007-present)

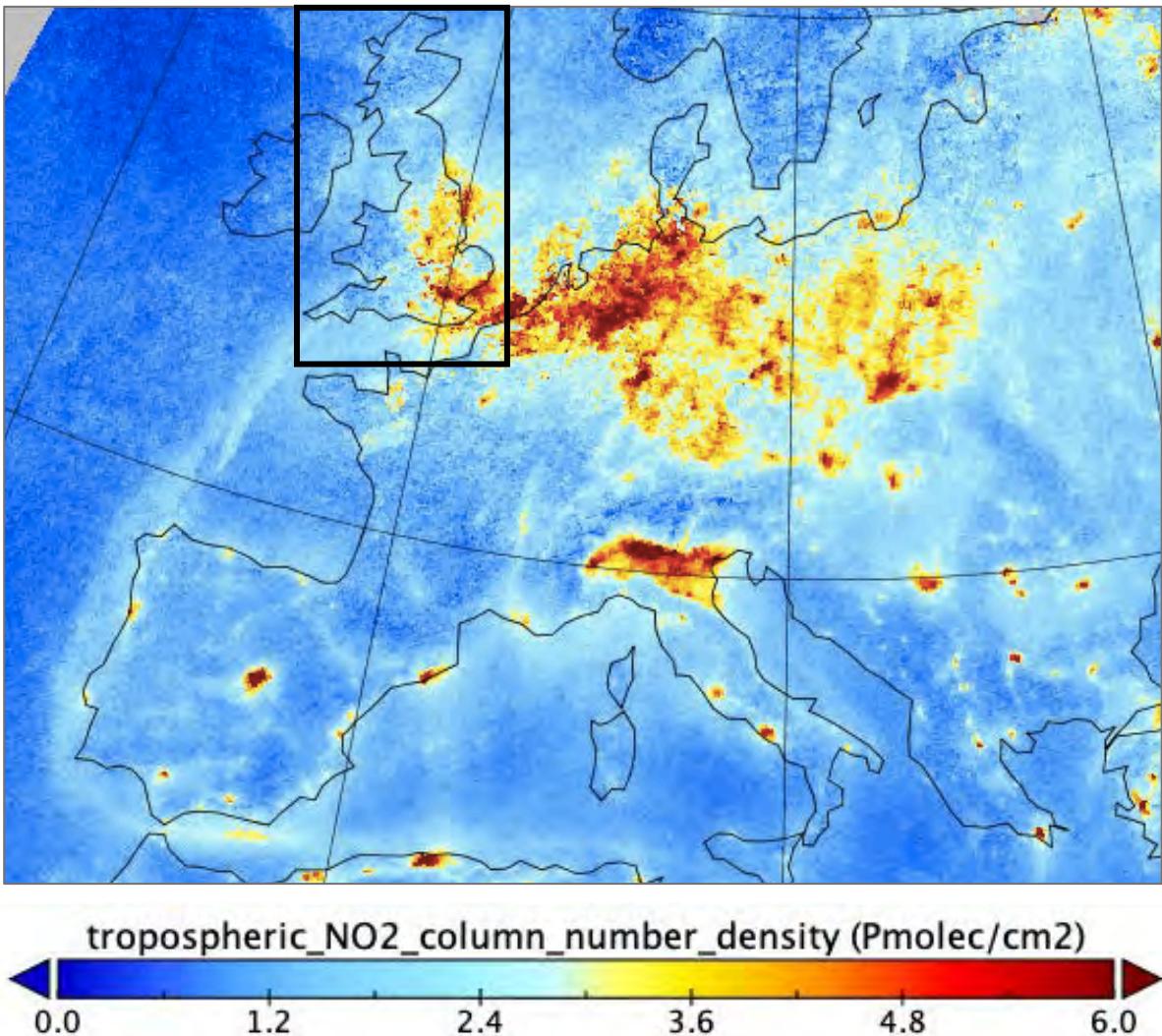
SCIAMACHY (200 km x 30 km, 2002-2012)

GOME (320 km x 40 km, 1995-2001)

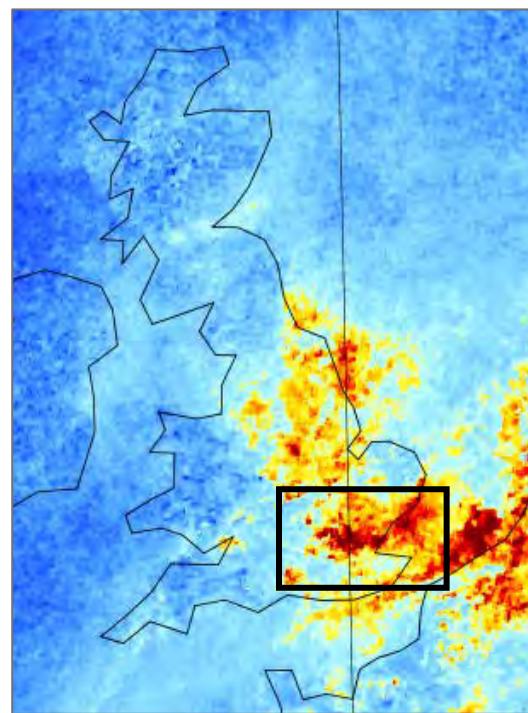
# What's happening?

High spatial resolution TROPOMI NO<sub>2</sub> (October 2019)

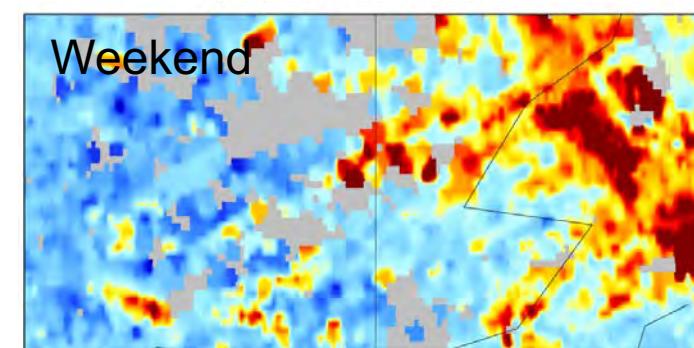
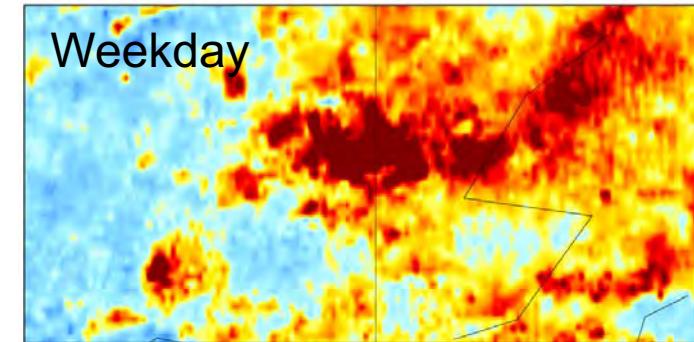
Europe



UK



London



Assess impact of lockdown?

# Conclusion and Next steps

- ✓ Satellite observations provide long-term and consistent global coverage of air pollutants
- ✓ Air quality related policies have been effective in the UK but no evidence observed yet for India
- ✓ Preliminary results show rapid increases in precursors of short-lived air pollutants for most future tropical megacities

Next, we will:

- Interpret the drivers of these trends
- Tease out biomass burning contribution to the trends
- Compare trends to widely used global emission inventories

Any Questions? Contact Karn ([kxv745@bham.ac.uk](mailto:kxv745@bham.ac.uk))



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