Using Satellite Observations to Launch Urban Air Quality Monitoring into the 21st Century

TRACE

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UNIVERSITY OF LEICESTER

Acknowledgements

Research Group

Collaborators and Contributors

CATAPULT Connected Places

CATAPULT Satellite Applications

Birmingham City Council

Leicester City Council

defra Department for Environment Food and Rural Affairs

UNIVERSITY OF BIRMINGHAM

Funding Support

NERC-funded EPSRC Researcher in Residence

NERC SCIENCE OF THE ENVIRONMENT

EPSRC Engineering and Physical Sciences Research Council

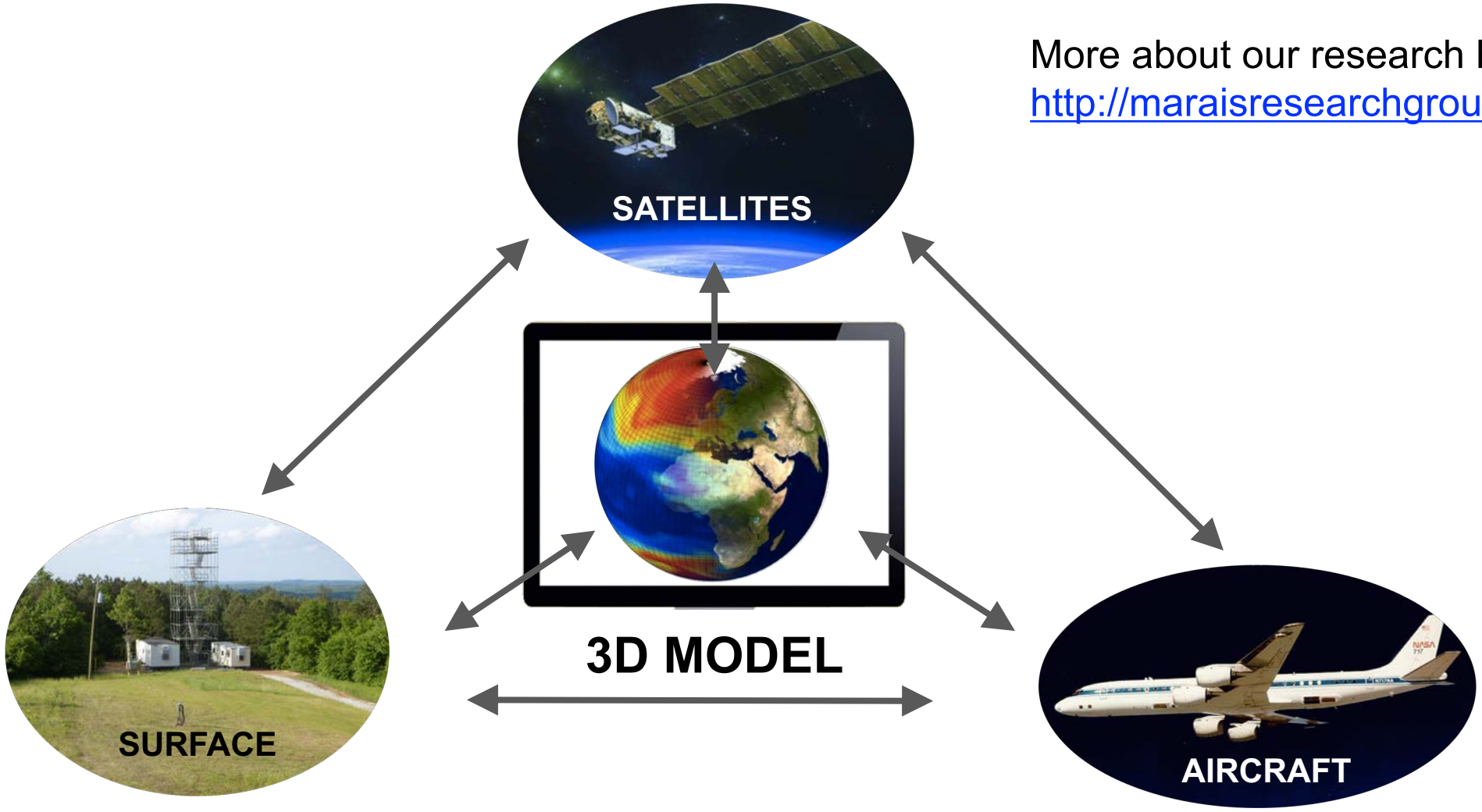
Copernicus accelerator

Copernicus Accelerator Mentor

Luísa Bernardes
Portugal Social innovation

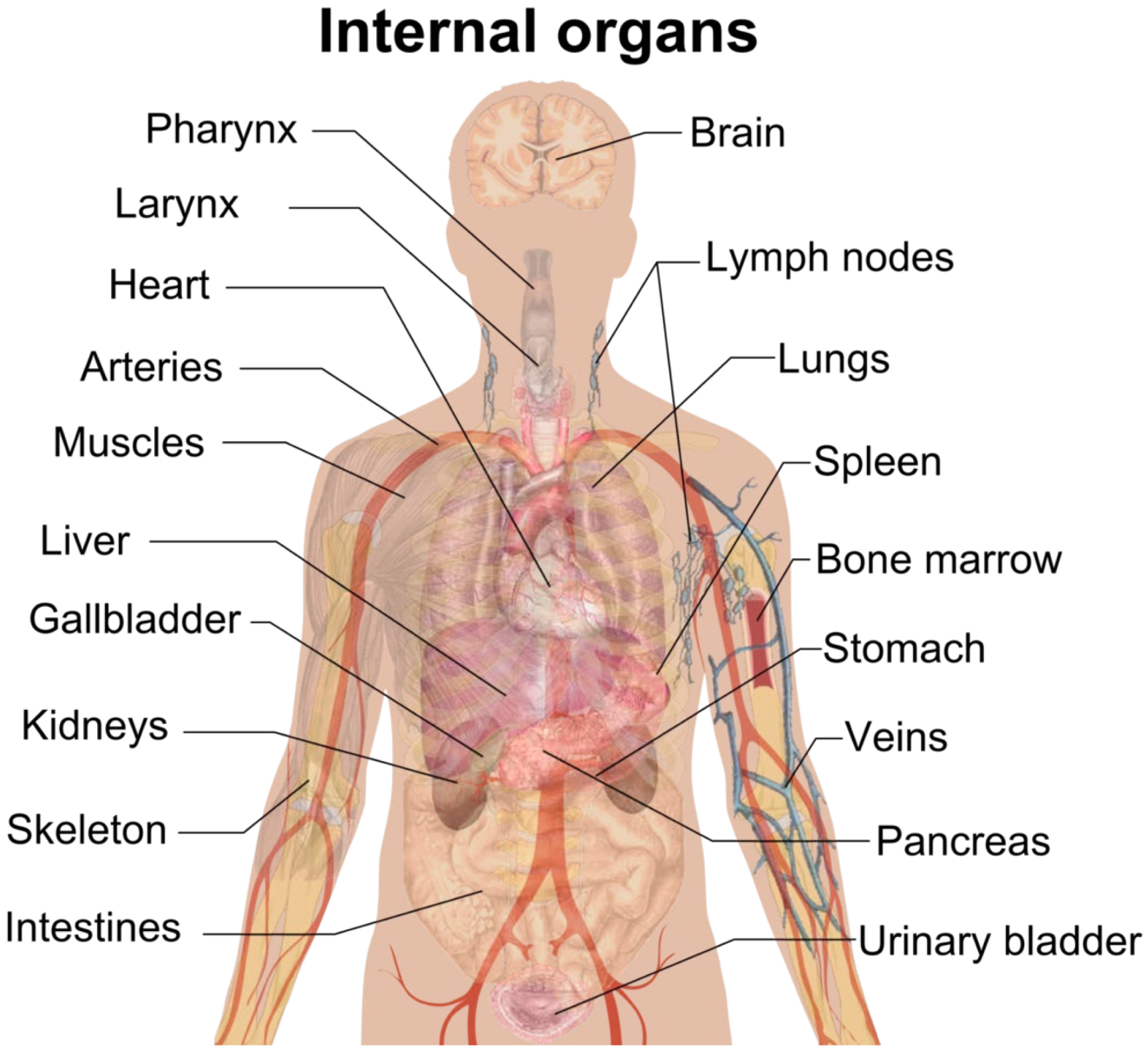
Atmospheric Chemistry and Air Quality Research

More about our research here:
http://maraisresearchgroup.co.uk/



Integrate data from multiple platforms to better understand atmospheric chemistry and inform prescient policy

Air Pollution is Pervasive



Every organ in our body may be susceptible to its deleterious effects

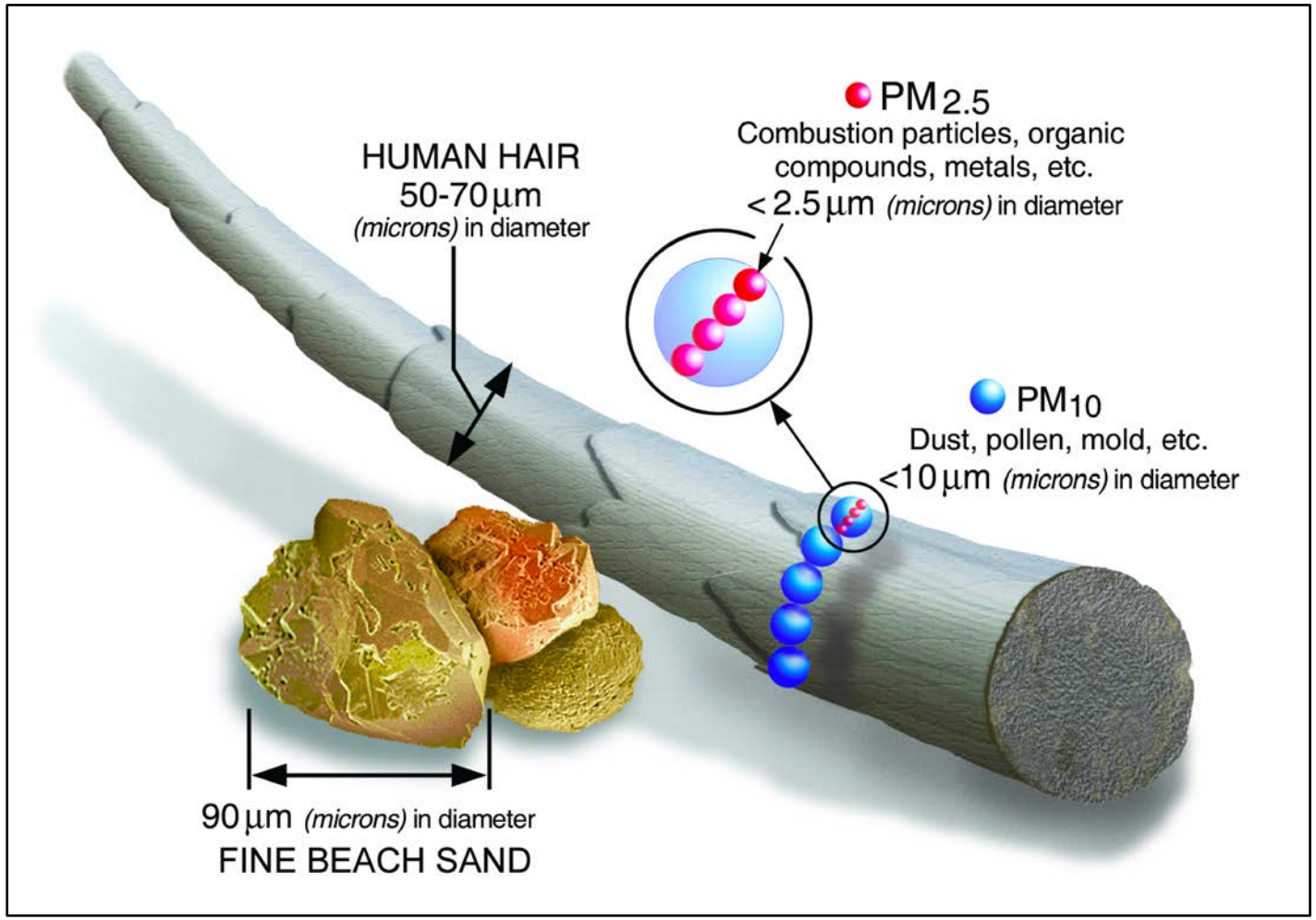
[Schraufnagel et al., 2019]

Recommended:
https://www.theguardian.com/environment/ng-interactive/2019/may/17/air-pollution-may-be-damaging-every-organ-and-cell-in-the-body-finds-global-review

Fine Particles ($PM_{2.5}$) are Most Deadly

$PM_{2.5}$:

Particles floating in the atmosphere that are small enough to penetrate deep into the lungs

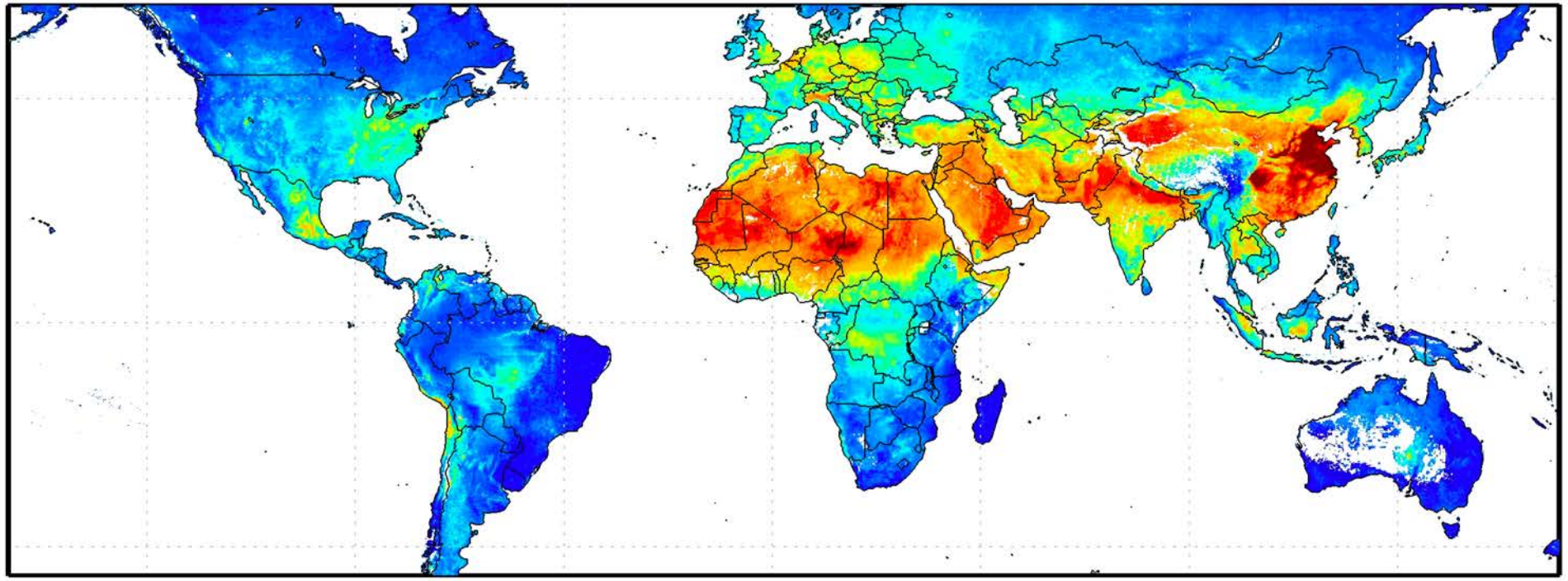


[US EPA]

Direct association between $PM_{2.5}$ exposure and hazardous health outcomes

Global Distribution of $PM_{2.5}$

Multiyear (2001-2006) Annual Average $PM_{2.5}$



WHO limit (future UK target)

UK limit

[van Donkelaar et al., 2010]

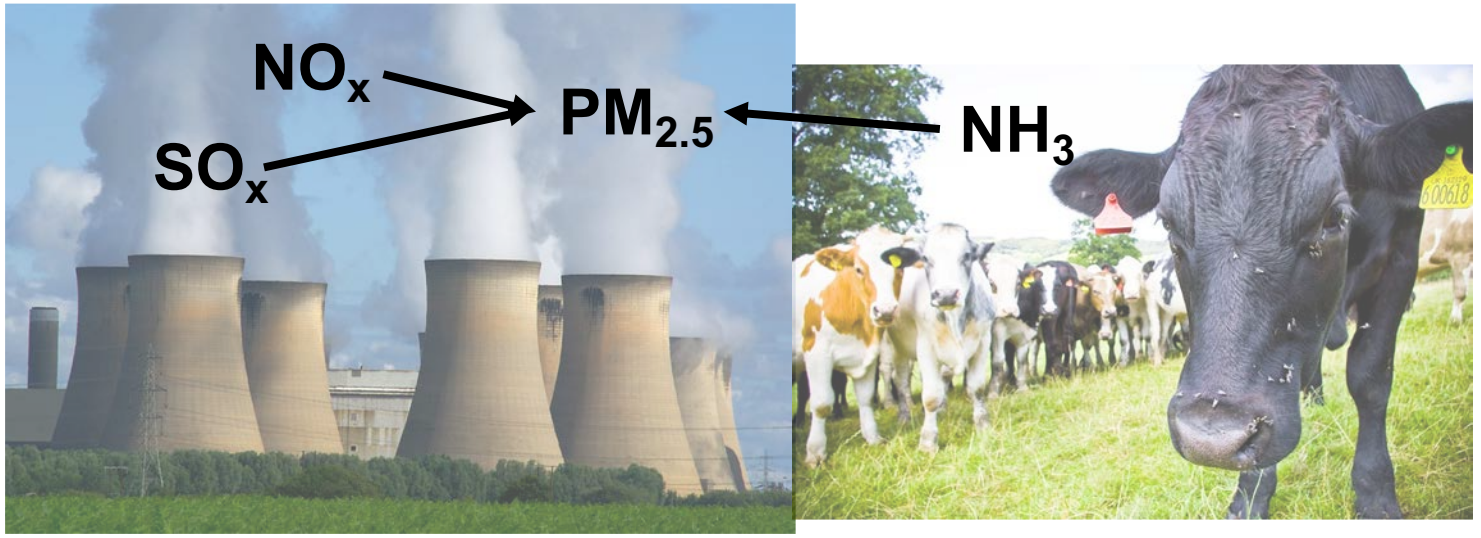
Most of the world is exposed to $PM_{2.5}$ above the WHO limit

$PM_{2.5}$ comes from Many Sources

Anthropogenic:
Energy generation, industry, agriculture, residential fuels, vehicles, construction, road dust, ...

Direct Emissions
(Primary)

Physical and Chemical Formation Processes
(Secondary)

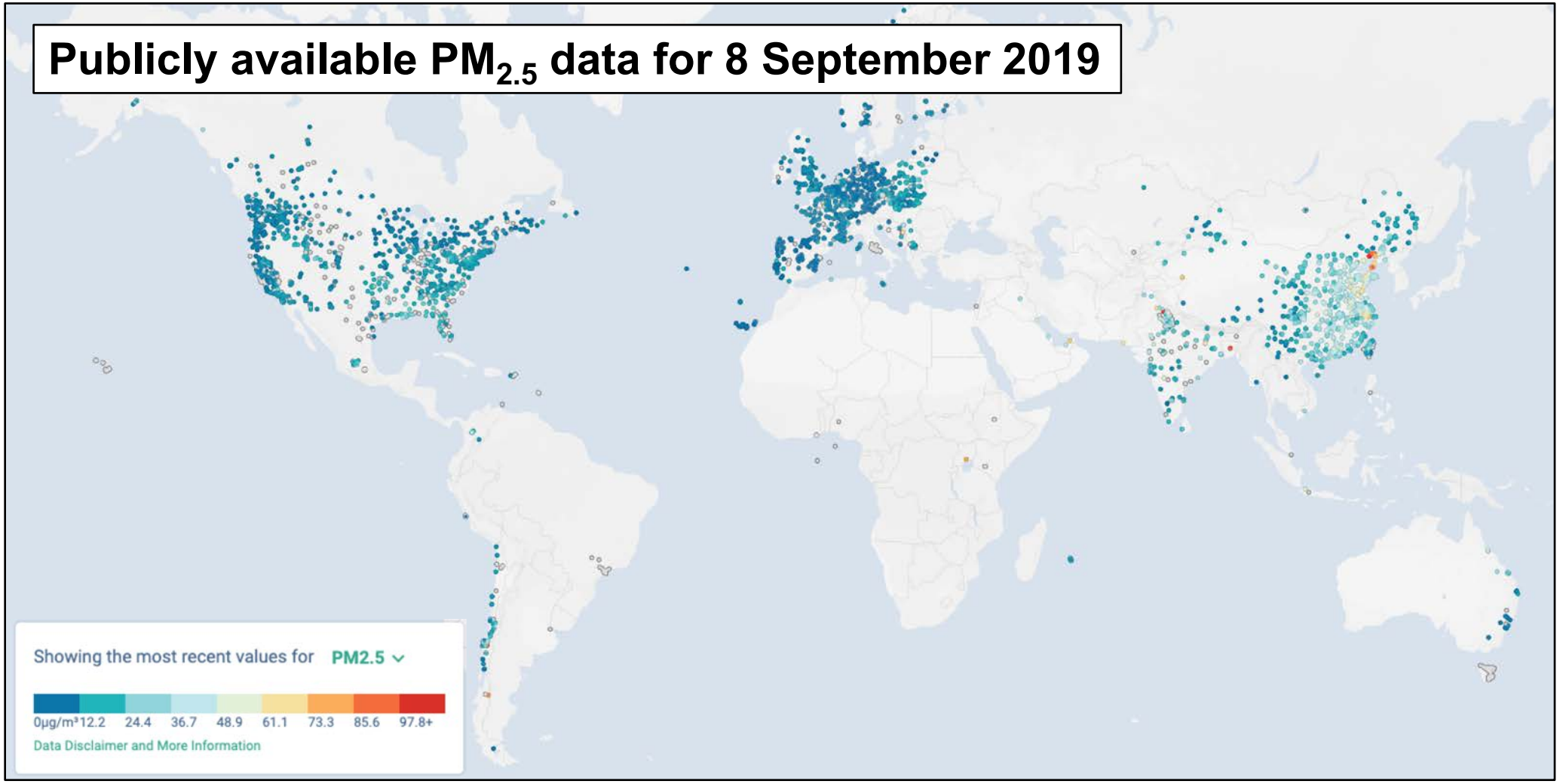


Also **natural sources**: ocean, soils, trees, wildfires, volcanoes, ...

This complexity makes it challenging to monitor and regulate

The Current Approach

No routine monitoring in many parts of the world



OpenAQ: https://openaq.org

The Current Approach

Large gaps in space, time and pollutants

UK monitoring network

London

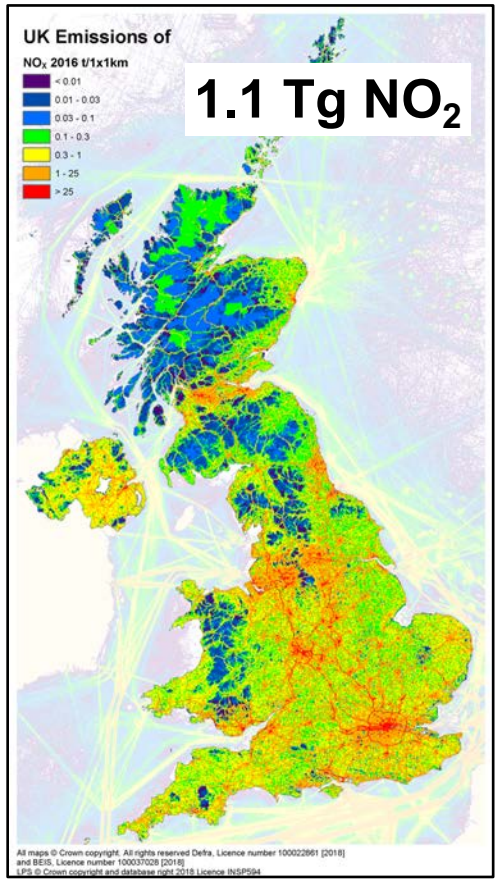
Birmingham

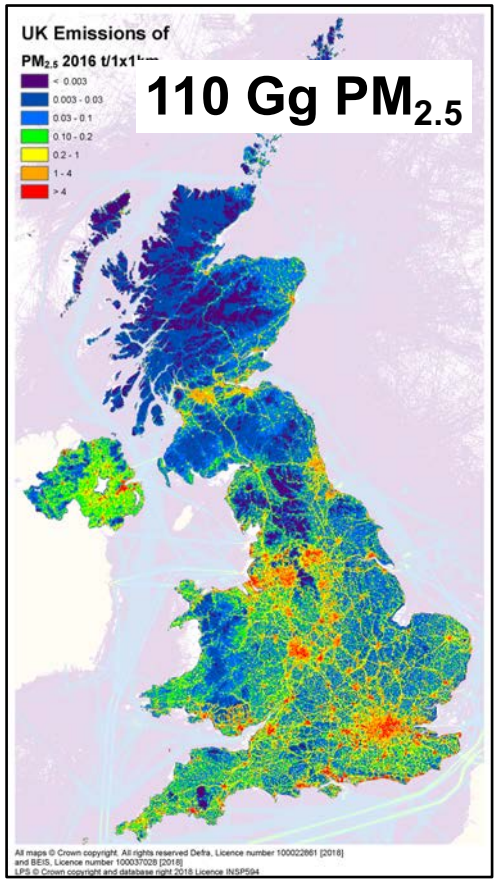
UK-AIR website: https://uk-air.defra.gov.uk/interactive-map

The Current Approach

Air quality monitoring tools can have large uncertainties

High Spatial Resolution UK Emissions Inventory





NAEI website: https://naei.beis.gov.uk/data/map-uk-das

Hinders development of effective policies and leads to large fines (>£60M)

The Solution

Earth observations are the only viable way to address deficiencies in air quality monitoring and management strategies!

TRACE

Tool for Recording and Assessing the City Environment

Data are freely available, but requires expertise to process and interpret

The Solution

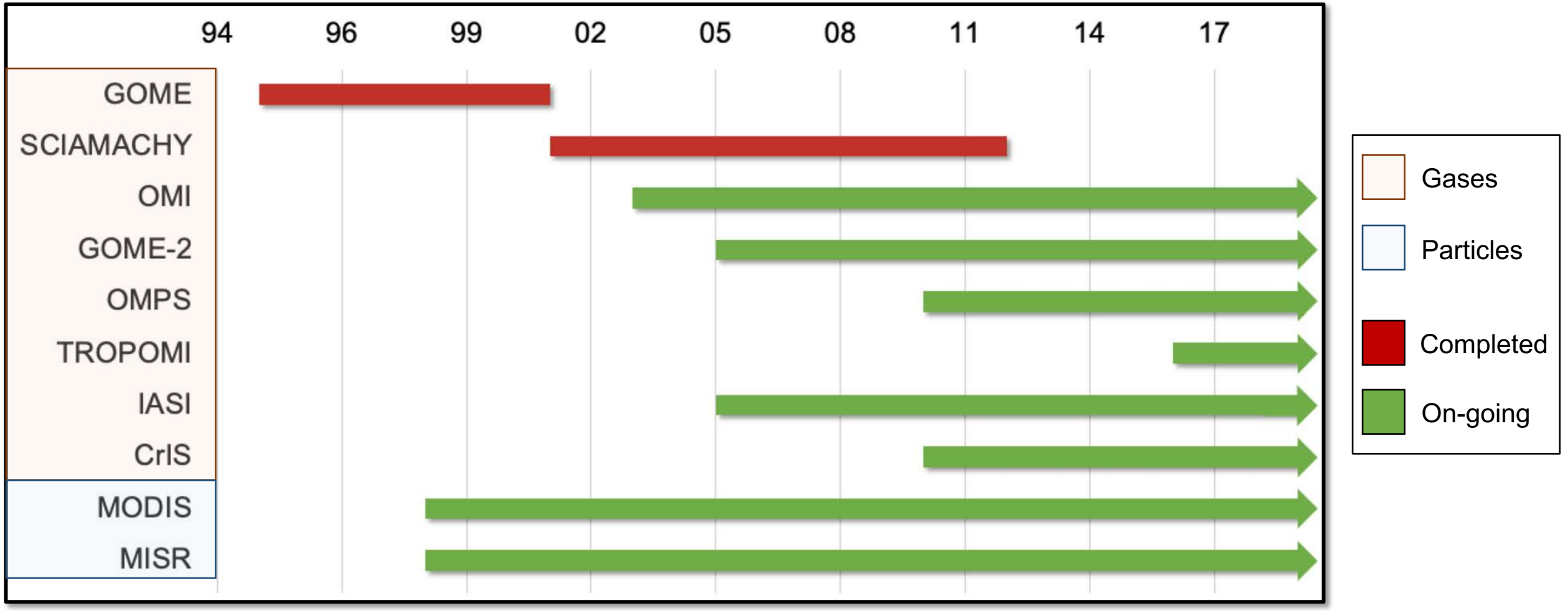
Products available from space-based instruments and relationship to air pollution

	Satellite Product	Air Pollutant
Gases	Nitrogen dioxide (NO_2)	NO_2
	Formaldehyde (HCHO)	Non-methane volatile organic compounds (NMVOCs)
	Ammonia (NH_3)	NH_3
	Sulfur dioxide (SO_2)	SO_2
	Carbon monoxide (CO)	CO
Particles ←	Aerosol optical depth (AOD)	$PM_{2.5}$

NMVOCs —oxidation→ **HCHO**

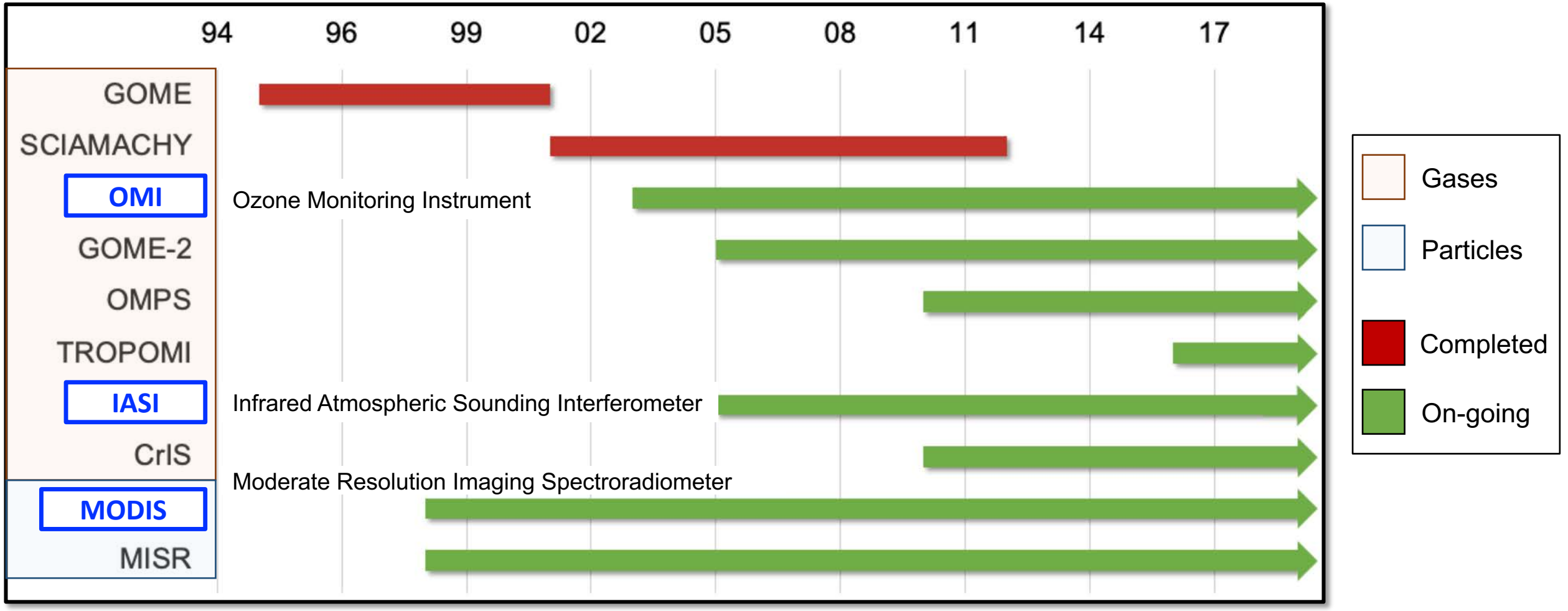
The Solution

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



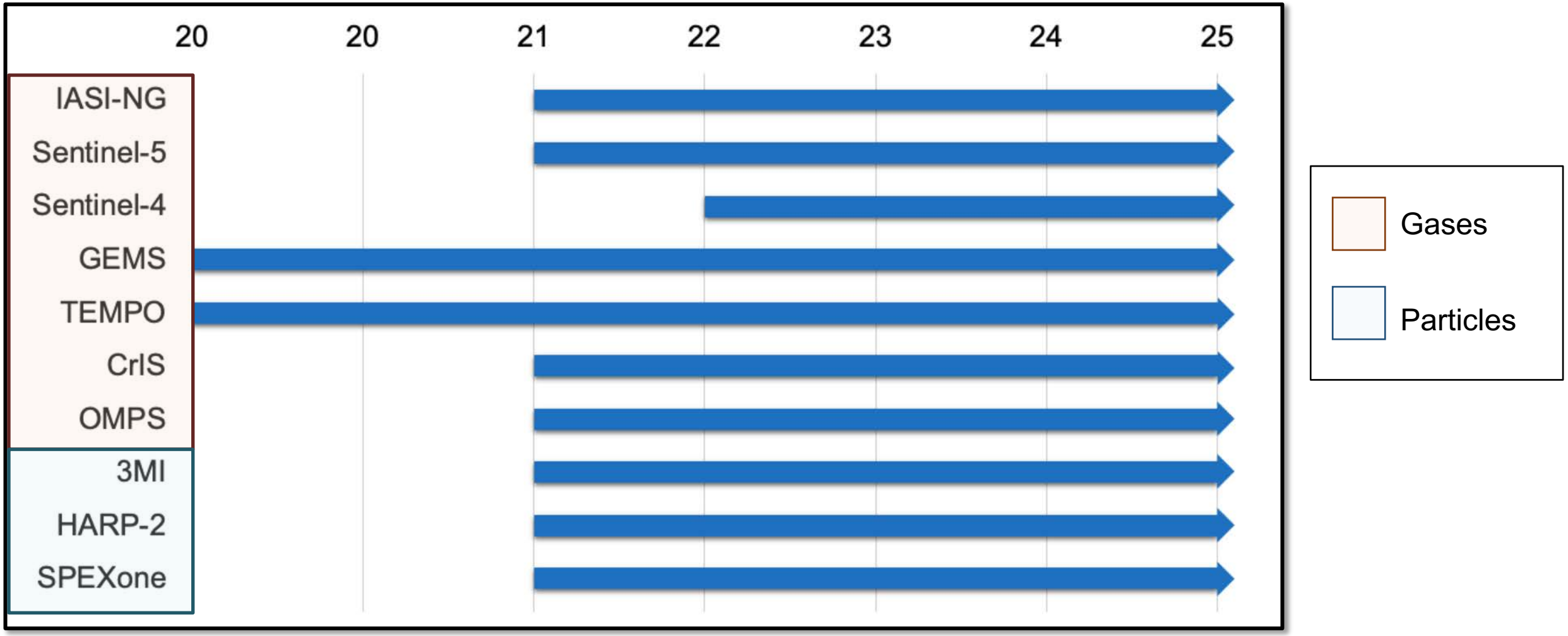
The Solution

What we're using to develop TRACE



The Solution

The future record will be at lower cost and finer scales than ever before



The Solution

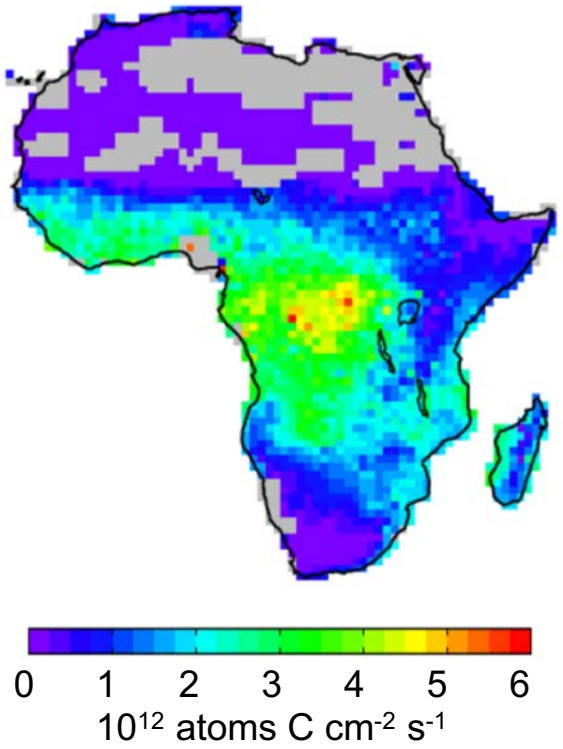
A data transformation and interpretation service to convert satellite observations into useful information about air quality.

Selected as Finalist for the Copernicus Masters Challenge

The Solution

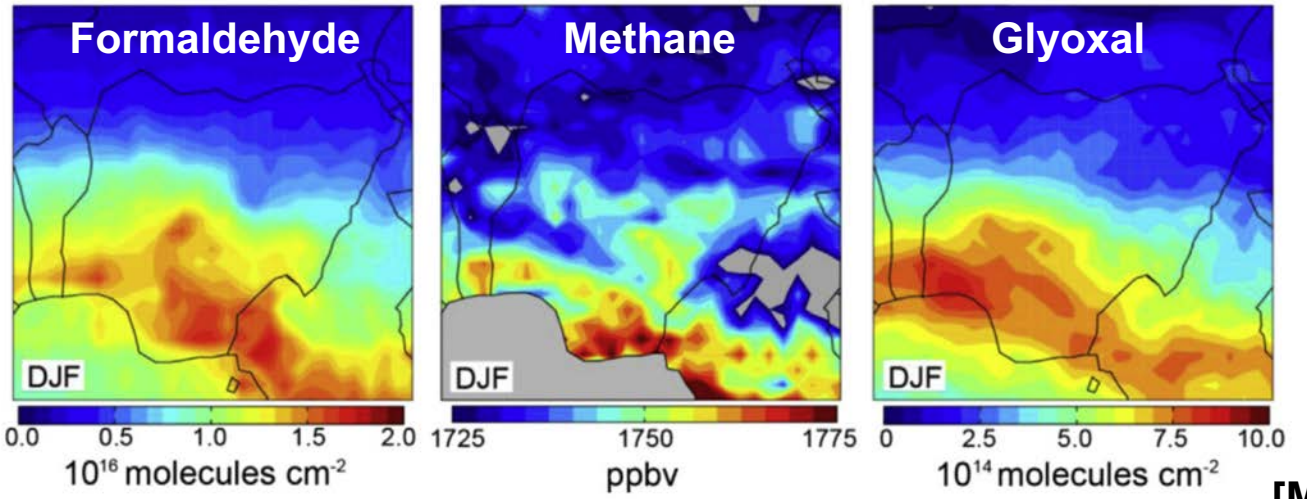
Widespread use in research; limited application to air quality policy

Biogenic Emissions from Trees in Africa



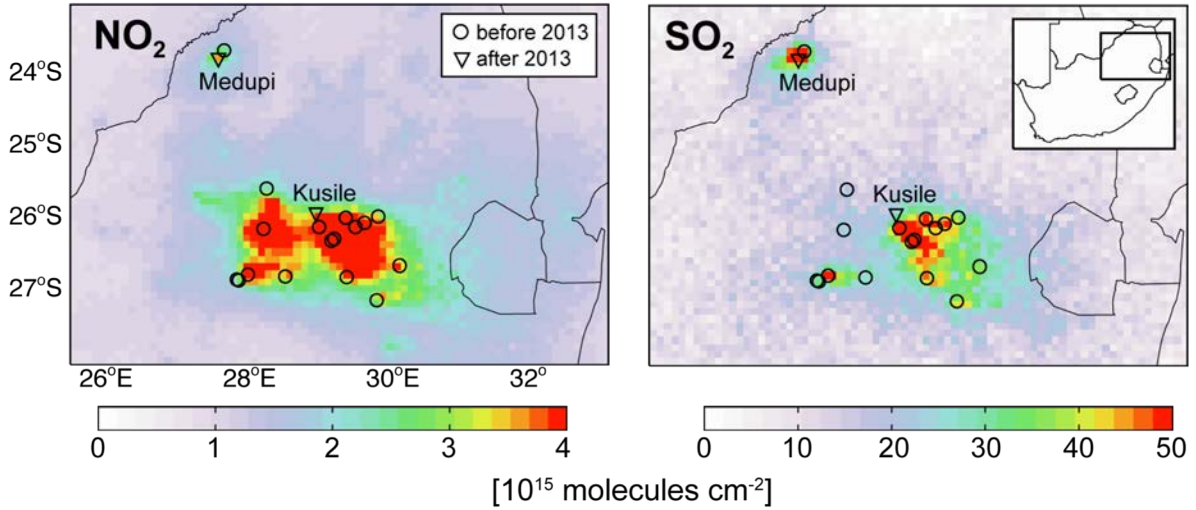
[Marais et al., 2012]

Identify and Interpret Pollution Sources in Nigeria



[Marais et al., 2014]

Combustion Emission Hotspots in South Africa

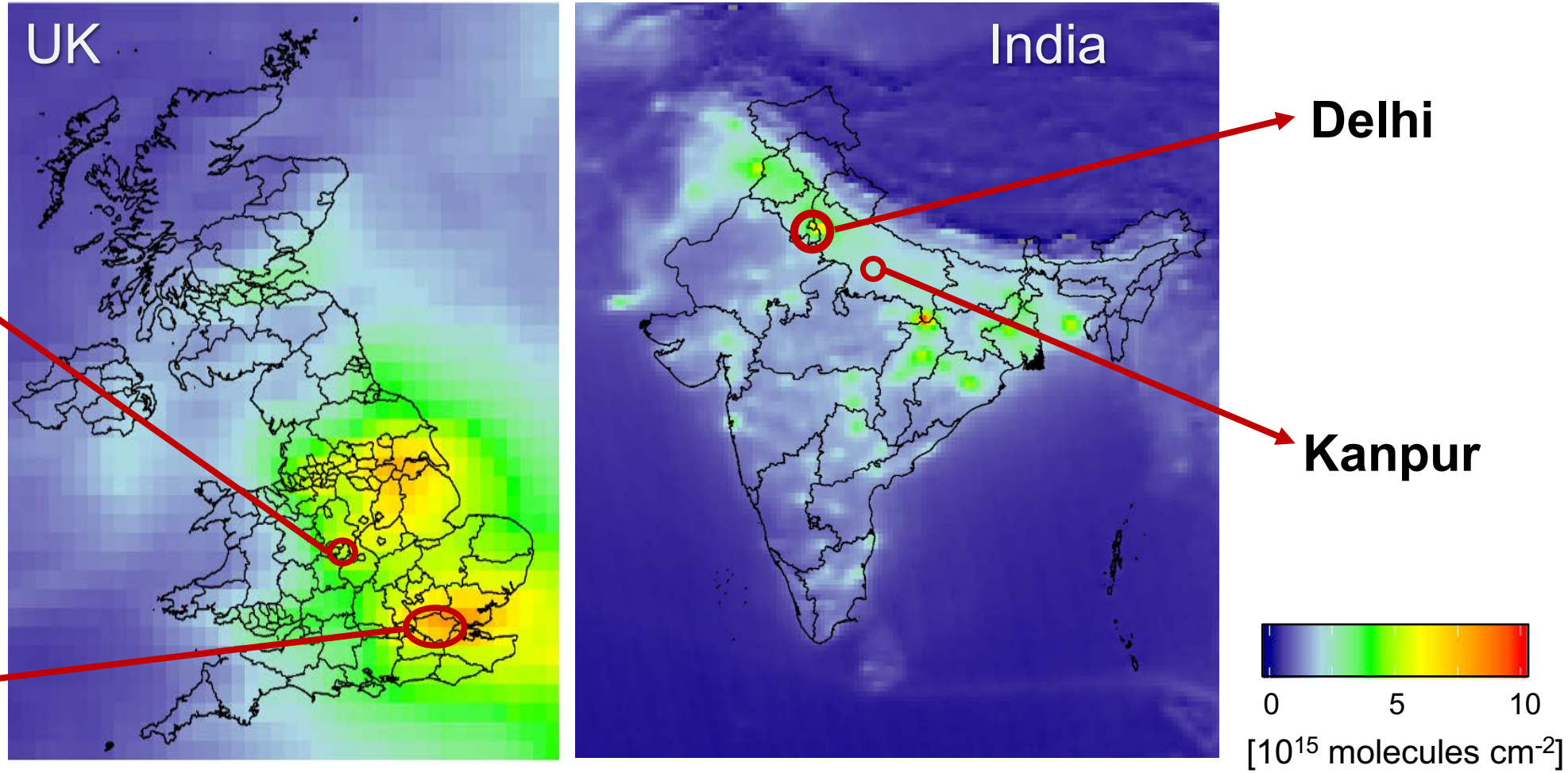


[Marais et al., 2019]

The Solution

Develop TRACE by targeting 4 dynamic cities and working with end users

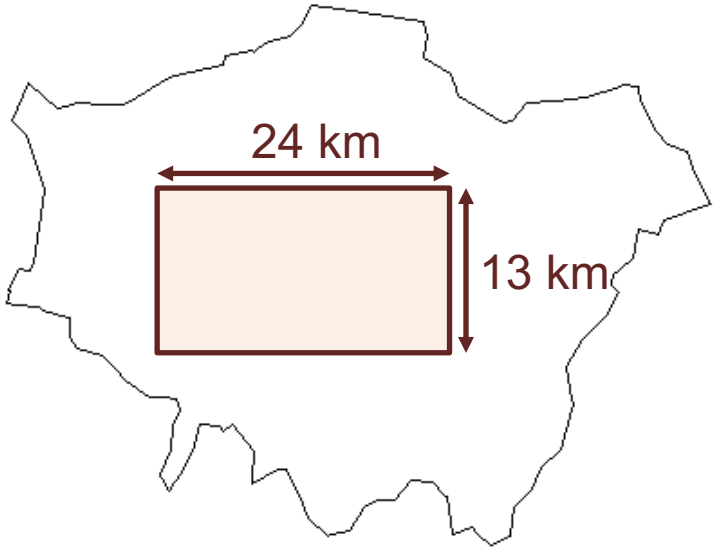
Background is multiyear (2005-2018) NO_2 from the OMI instrument



The Solution

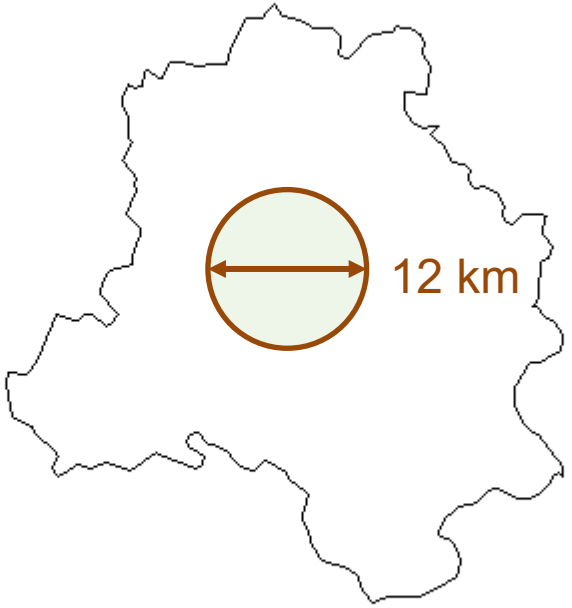
Relevant space-based instruments have coarse spatial resolution

OMI
Ozone Monitoring Instrument



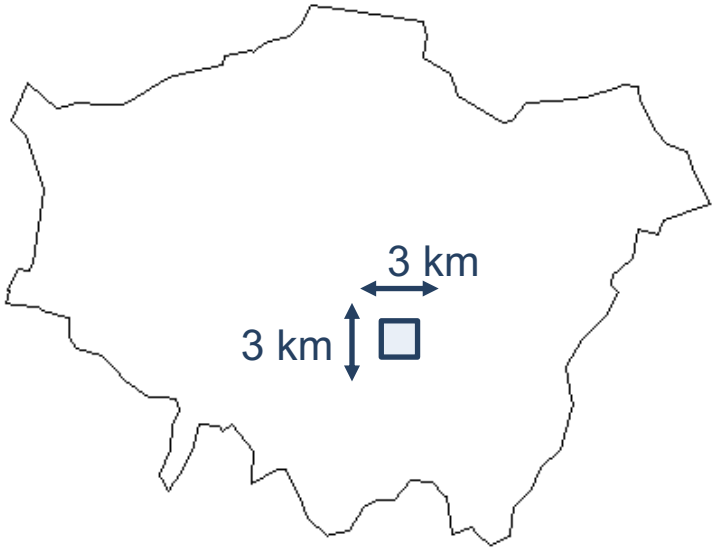
London
(1600 km^2)

IASI
Infrared Atmospheric Sounding Interferometer



Delhi
(1500 km^2)

MODIS
Moderate Resolution Imaging Spectroradiometer



London
(1600 km^2)

Use to monitor and assess air quality throughout large cities

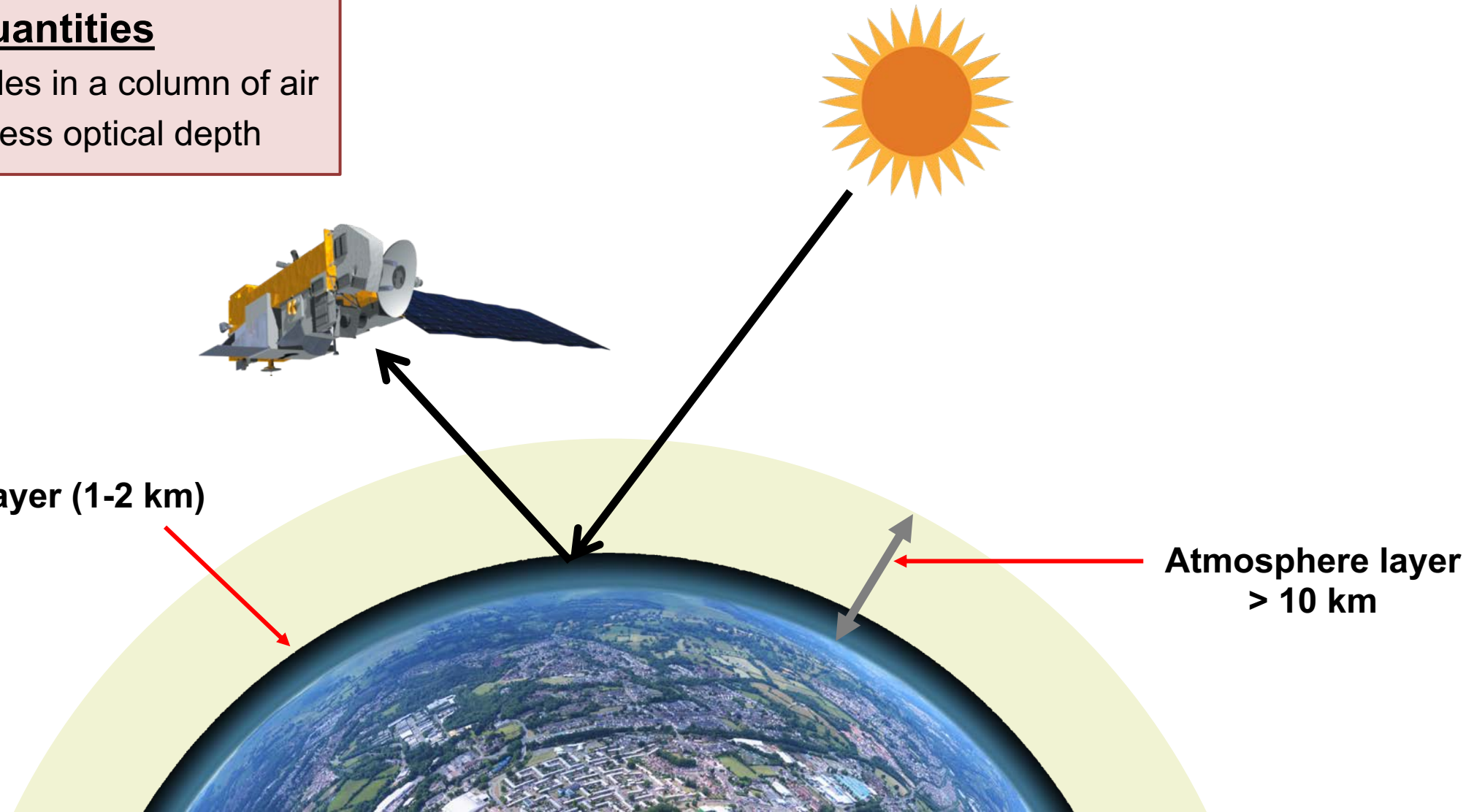
The Solution

Satellites measure solar backscattered light through the whole atmospheric column

Measured quantities

Gases: Molecules in a column of air

Aerosols: Unitless optical depth

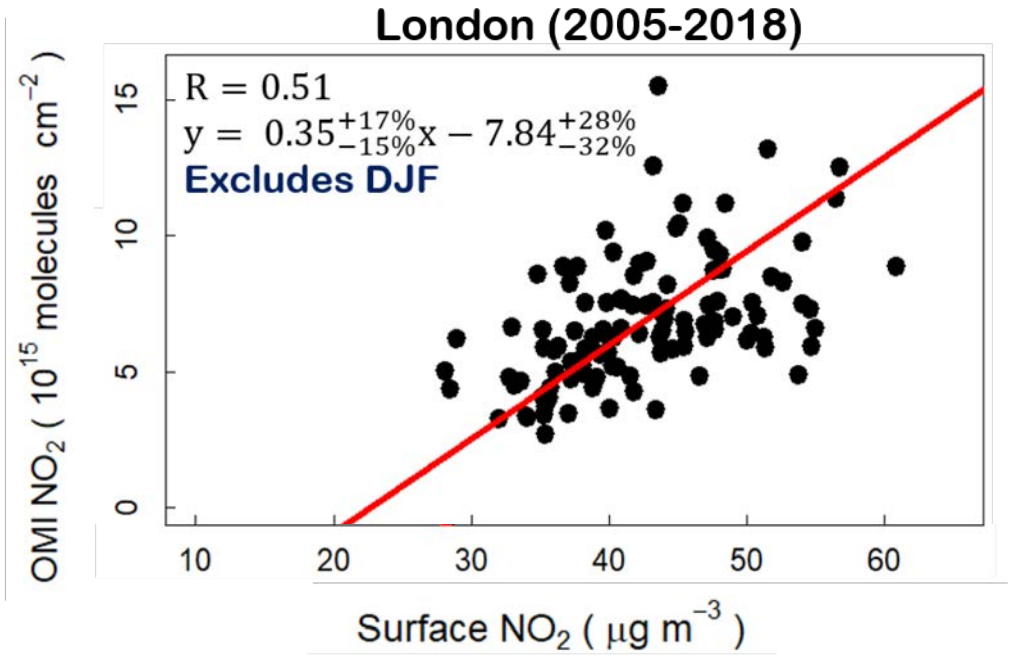


The Product

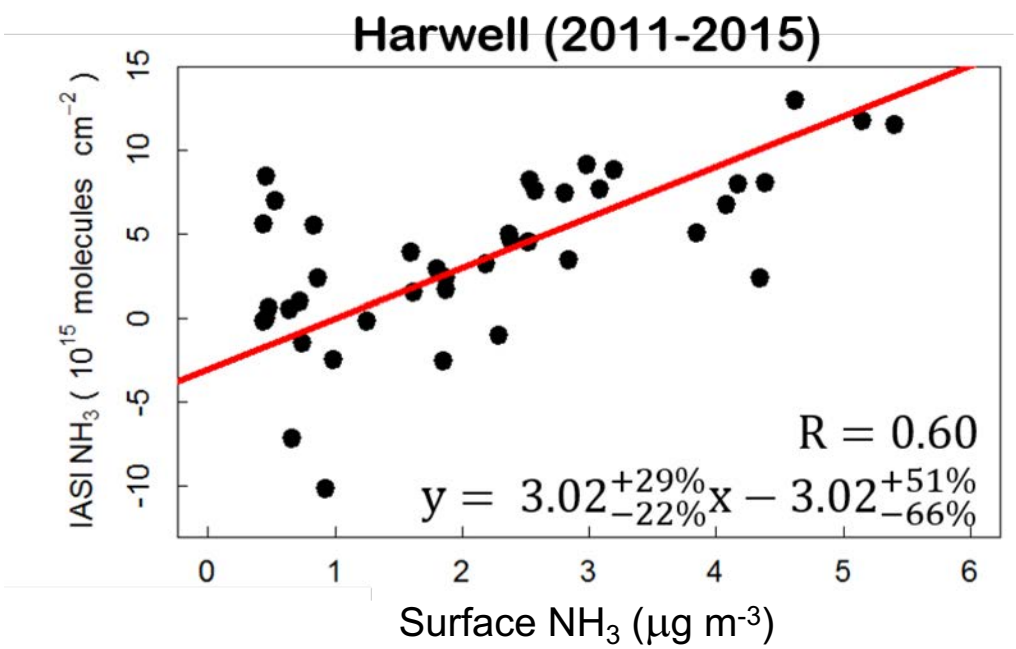
Quality Assurance:

Quality checks with surface observations where these are available

Satellite versus surface NO_2 in London



Satellite versus surface NH_3 at the supersite n Harwell



Points are monthly averages

Pearson's correlation coefficient (R value) indicates consistency

The Product

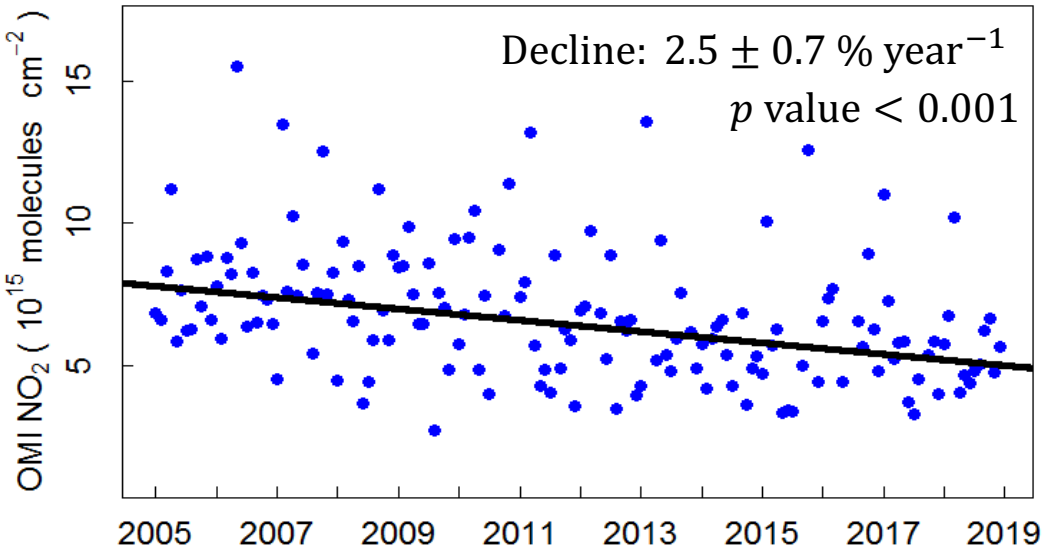
Quality Assurance Progress

Component	Completed	Passed
NO_2		
NH_3		
SO_2		
AOD		
HCHO		
CO		

The Product

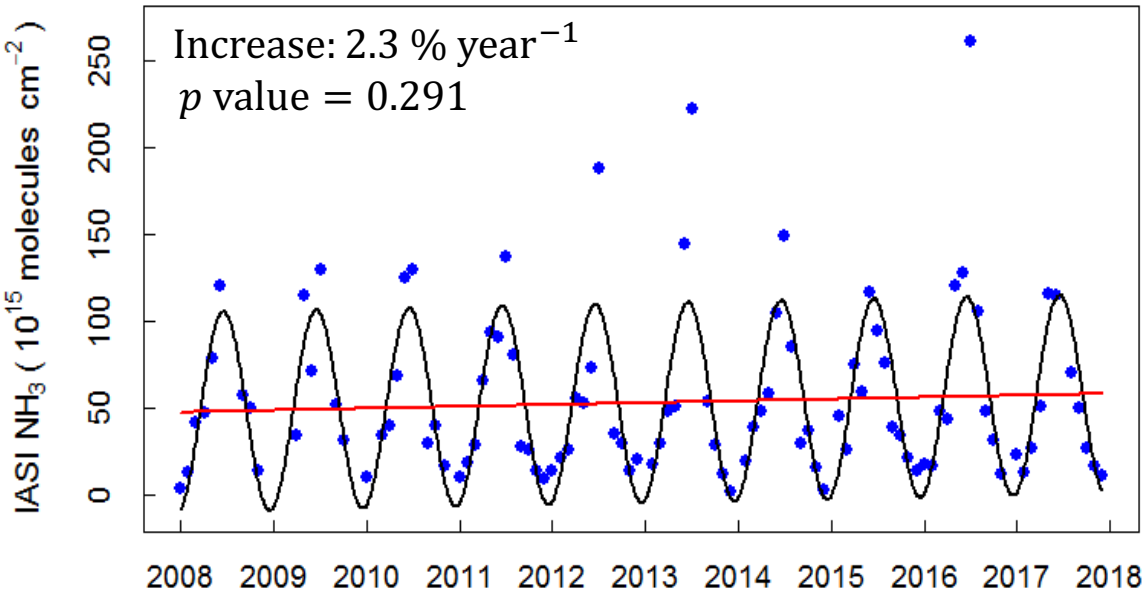
We use robust statistics to derive long-term trends

London NO_2



Decline according to the monitoring network only **1.8% year^{-1}**

Delhi NH_3

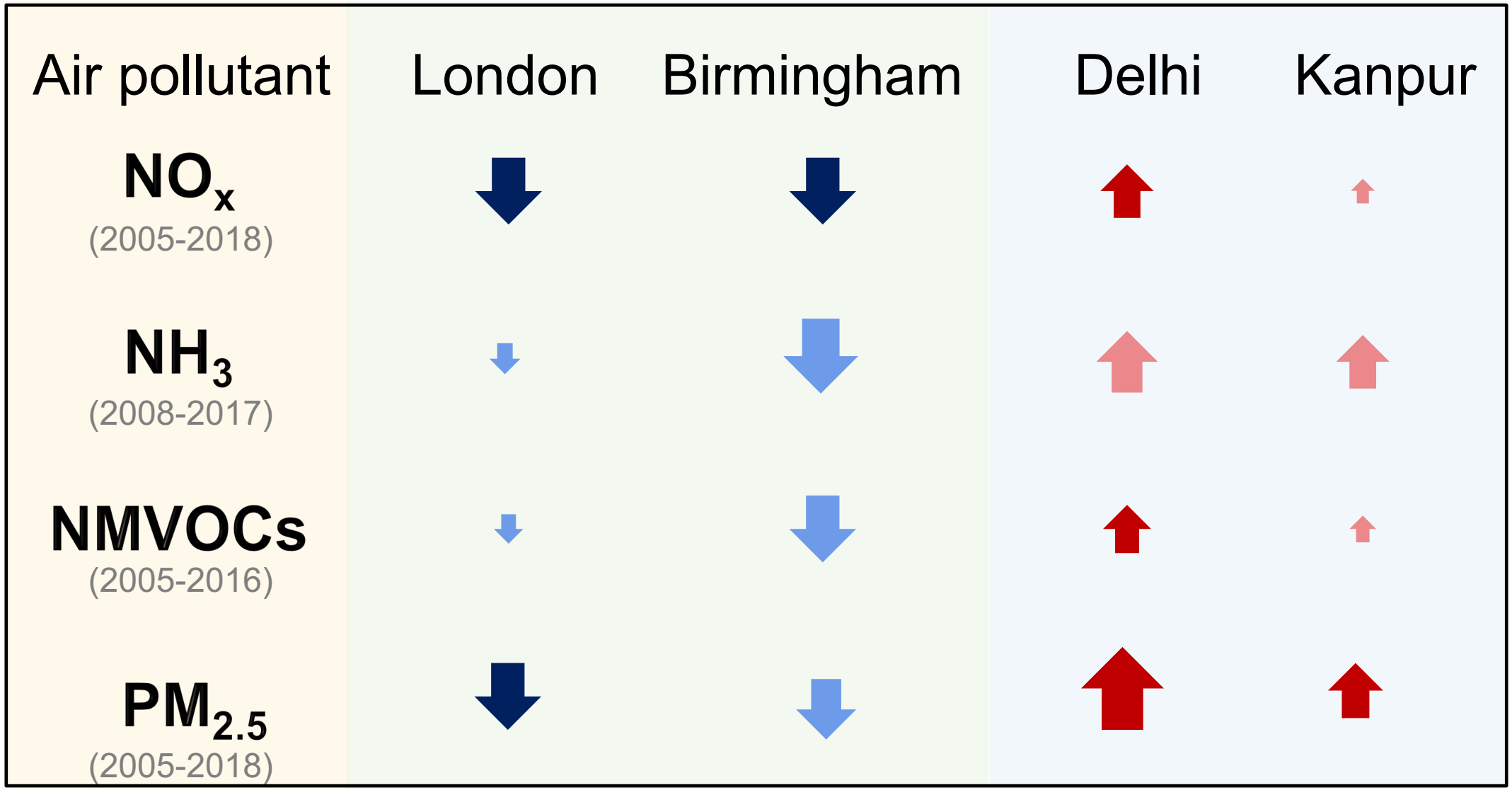


No surface network or publicly available model data to compare to satellite-derived estimate

We apply trend analysis to all atmospheric components in all 4 cities

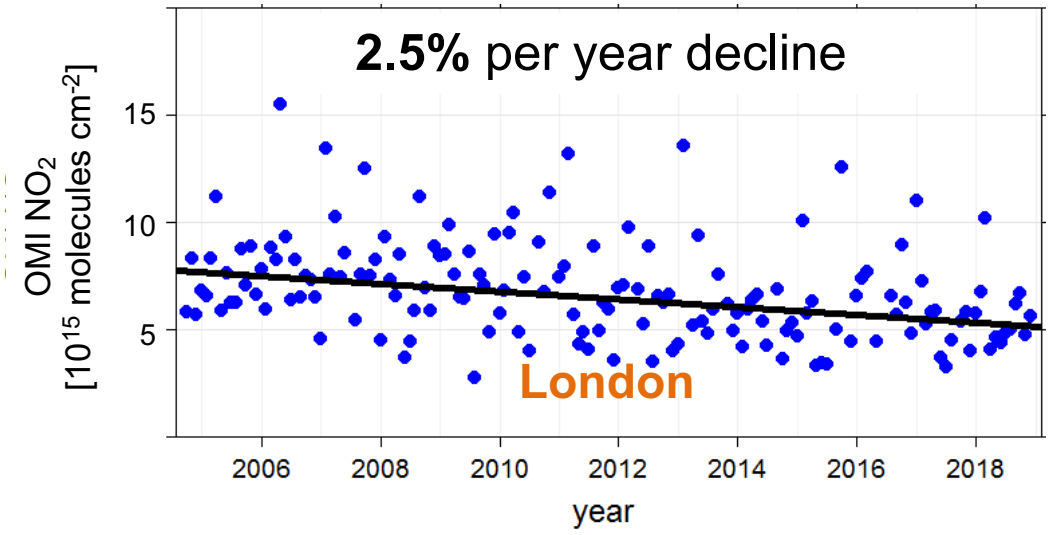
The Product

Long-term trends in pollutants for the four target cities



The Product

Business-as-usual ability to meet air quality standards

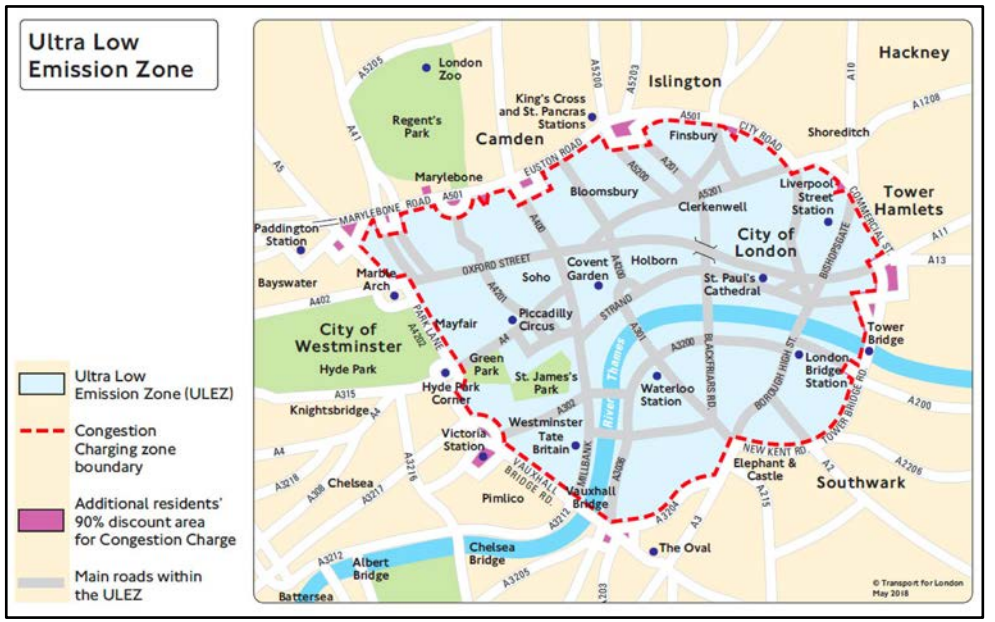


NO_2 standard for UK and India:
40 μg m^{-3} (annual mean)

London Marylebone site:
85 μg m^{-3} in 2018
(current approach will take **45 years** to be compliant)

Will the ULEZ be enough to meet targets?

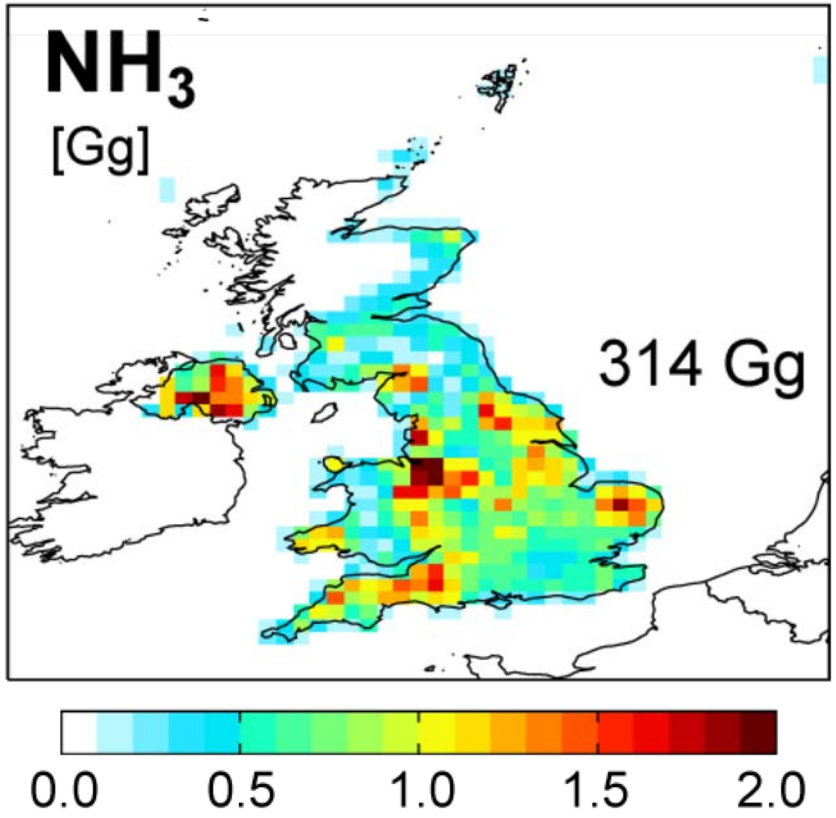
Use TRACE to monitor efficacy of ULEZ



Ongoing and Upcoming Developments

Improve the UK National Emissions Inventory

UK inventory of NH_3 emissions



>80% from agriculture

Increasingly important precursor of $PM_{2.5}$

NH_3 —partitions to aerosol→ $PM_{2.5}$

Opportunities to Join The Team

Opportunities posted here: http://maraisresearchgroup.co.uk/joinus.html

Current Opportunities:

ESA Living Planet Fellowship (Closes 1 November):
https://eo4society.esa.int/2019/09/04/call-for-lpf-research-proposals-2019/

Schlumberger Faculty for the Future (Closes 7 November):
https://facultyforthefuture.net/

Near-Future Opportunties:

NERC CENTA Doctoral Training Programme (opens November 2019):
http://www.centa.org.uk/
Contact me (eloise.marais@le.ac.uk) if interested/willing in providing CASE support

ERC postdoctoral researcher (advertising opens soon)

Thank you for your time!

TRACE