IMPERIAL

Dr Gary Fuller

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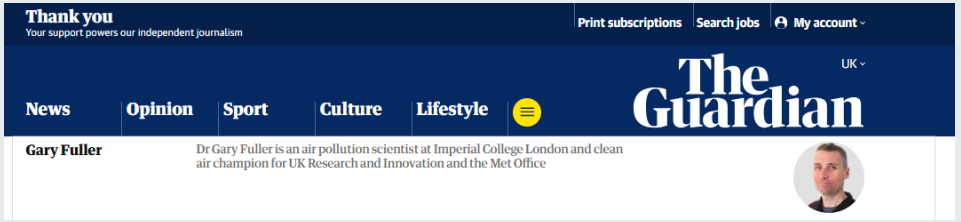
Air pollution and sources

Senegal – AirAware
Online - June 2025

Clean Air Programme
www.ukcleanair.org/



Aim:

To help epidemiologists and public health practitioners to understand the air pollution science that affects the design and interpretation of their studies.

Objectives:

By the end of the session, you should:

- Know the main air pollutants of health concern, and their sources, and that PM2.5 is not a single pollutant.
- Understand the differences between primary and secondary pollutants and the difficulties that this creates for air pollution management.
- Have an overview of the global air pollution.
- Understand the differences, strengths and weaknesses in different types of air pollution exposure data: ground measurements, satellite data and models.
- Be aware of temporal corelations between pollutants.
- Be familiar with the HEI accountability chain between sources and health impacts.

Main air pollutants of health concern

What are the main air pollutants and sources?

Published in 2021:

https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines

Pollutant	Averaging Time	2005 AQGs	2021 AQGs
$PM_{2.5}$, μg/m^3	Annual	10	5
	24-hour[a]	25	15
PM_{10}, μg/m^3	Annual	20	15
	24-hour[a]	50	45
O_3, μg/m^3	Peak season[b]	-	60
	8-hour[a]	100	100
NO_2, μg/m^3	Annual	40	10
	24-hour[a]	-	25
SO_2, μg/m^3	24-hour[a]	20	40
CO, mg/m^3	24-hour[a]	-	4

Also recommendations for more research on black carbon and UFP

What are the main air pollutants and sources?

The full list of pollutants that have defined air quality standards in the UK largely reflect the European Union Directives:

Gases

- Nitrogen dioxide (NO2) – traffic, gas heating, industry
- Ozone (O3) – forms in air from methane, solvents, petrochemicals, traffic
- Sulphur dioxide (SO2) – coal and oil – shipping and industry
- Carbon monoxide (CO) – traffic but low these days
- Benzo[a]pyrene (B[a]P) – burning carbon-based fuels
- Benzene – petrochemicals and solvents
- 1,3-butadiene – petrochemicals

Particulates

- Particulate Matter (PM10) – wood & coal burning, traffic industry, agriculture construction
- Fine Particulate Matter (PM2.5) - wood & coal burning, traffic industry agriculture
- Lead (Pb) – industry (no Pb in road petrol these days)
- Nickel (Ni) - industry
- Cadmium (Cd) - industry
- Arsenic (As) – industry, coal and waste wood burning

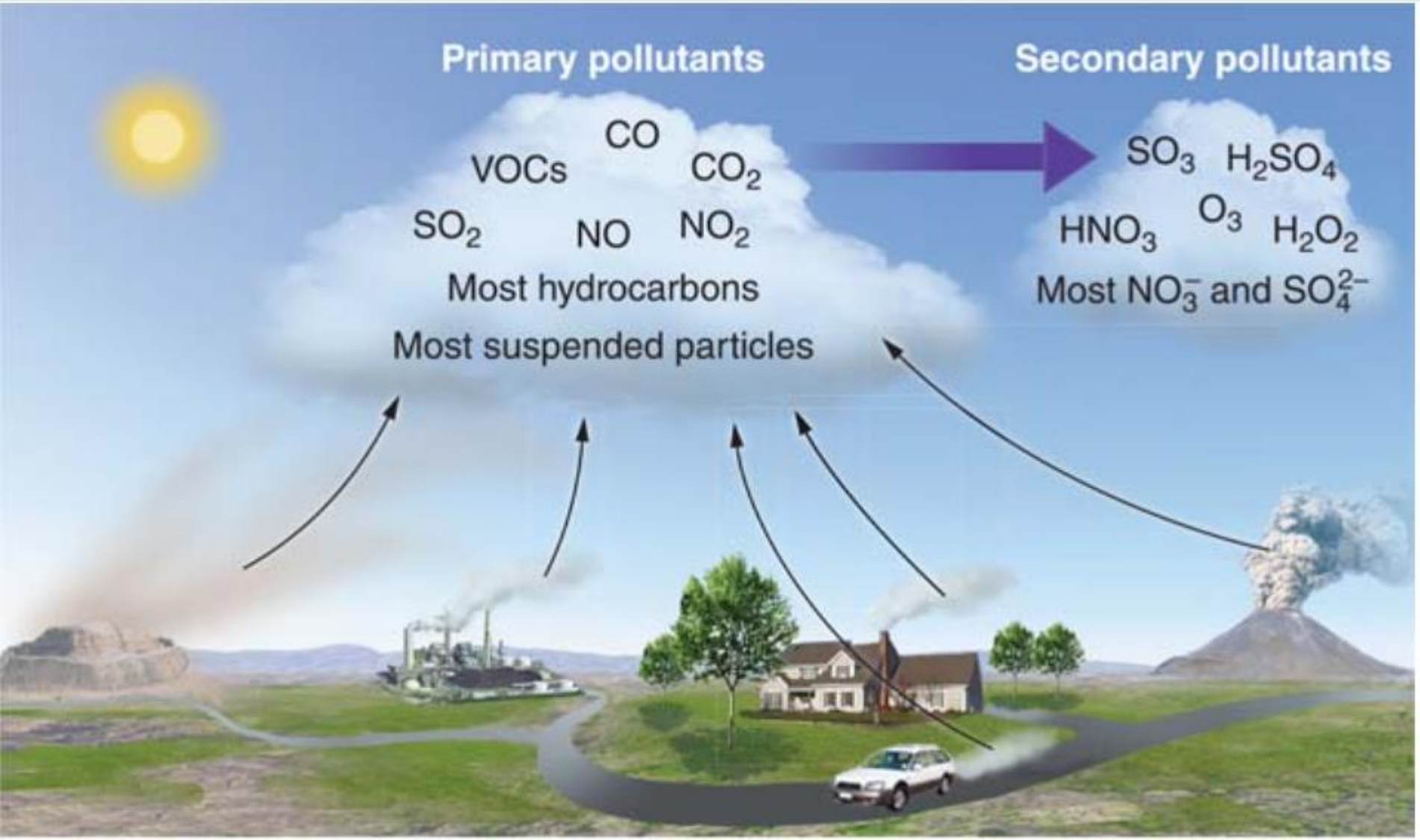


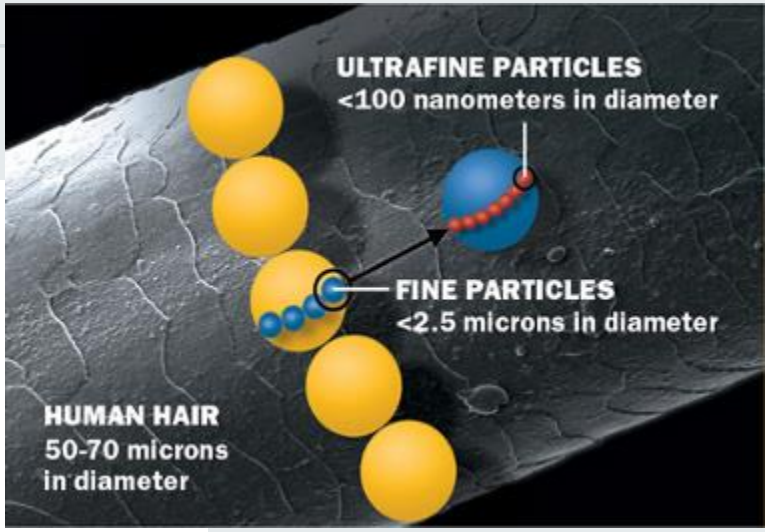
Figure 46.3

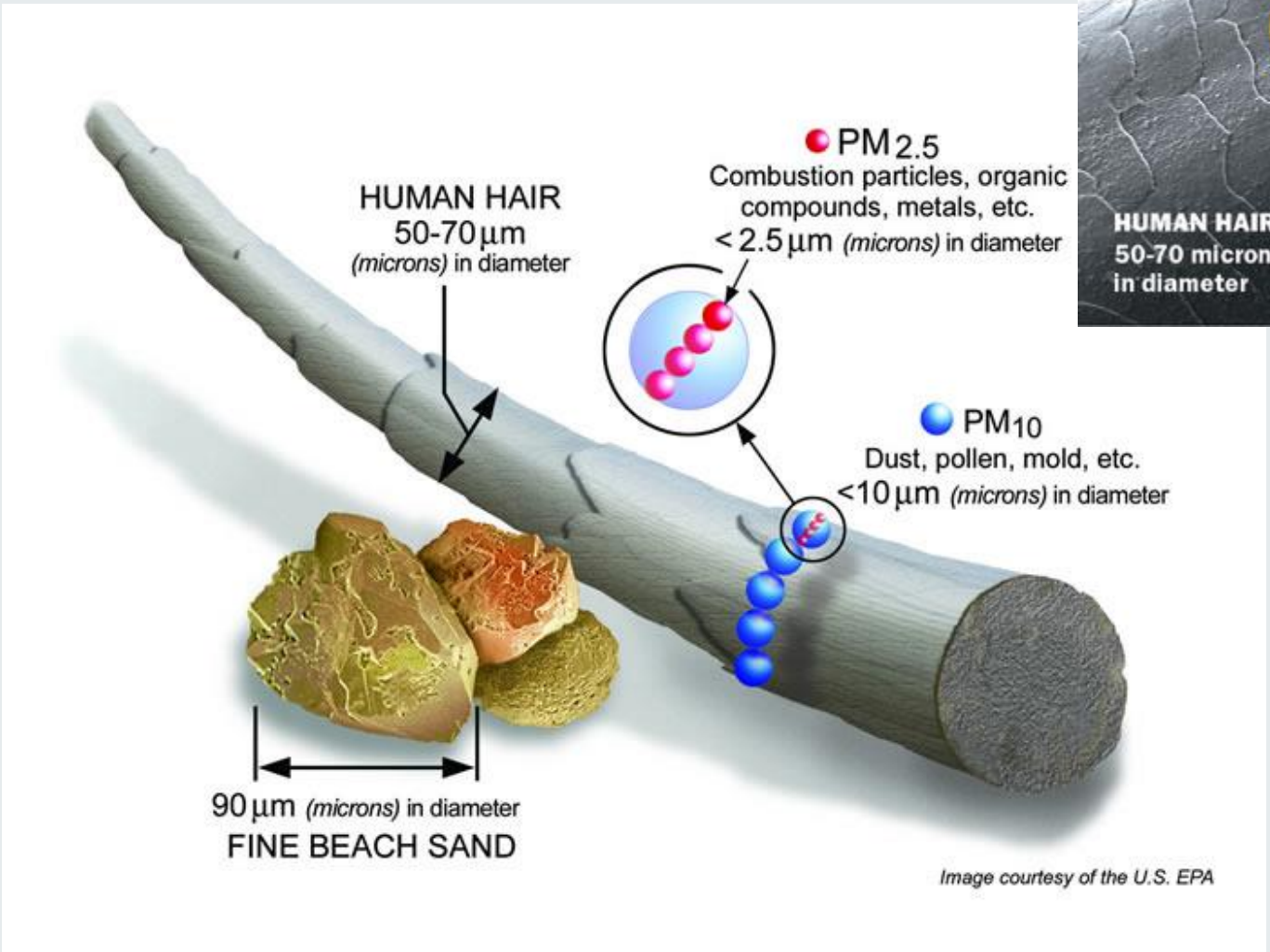
Friedland, *Environmental Science for AP®*, 2e, © 2015 W.H. Freeman and Company

FIGURE 46.3 **Primary and secondary air pollutants.** The transformation from primary to secondary pollutant requires a number of factors including sunlight, water (clouds), and the appropriate temperature.

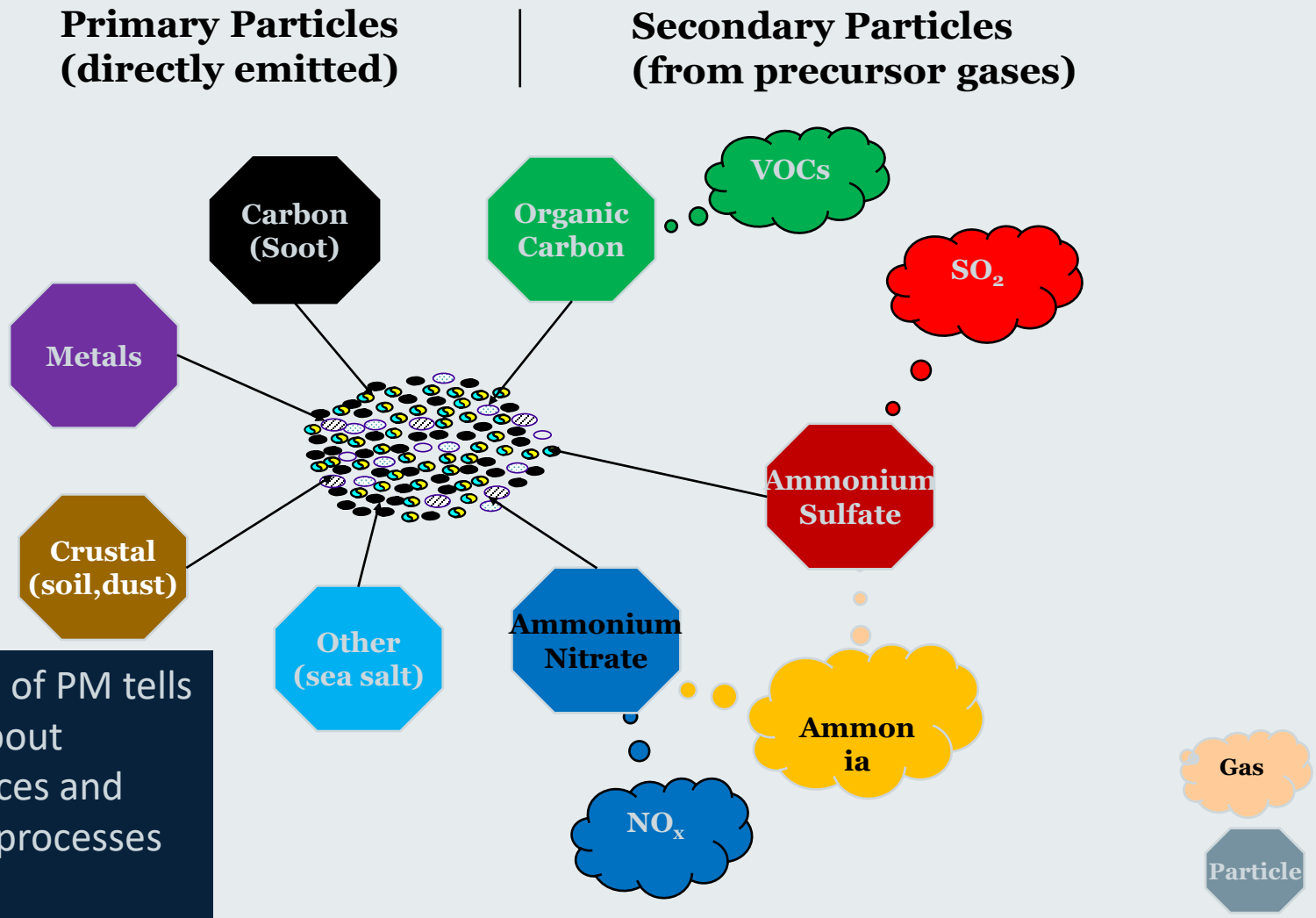
PM10, PM2.5 and ultrafine particles

– 3 orders of magnitude





PM2.5 and PM10 are not single pollutants



Composition of PM tells us about the sources and formation processes

Which is the most harmful?

borrowed from David Green

Air pollution around the globe

Air pollution is a global health emergency*

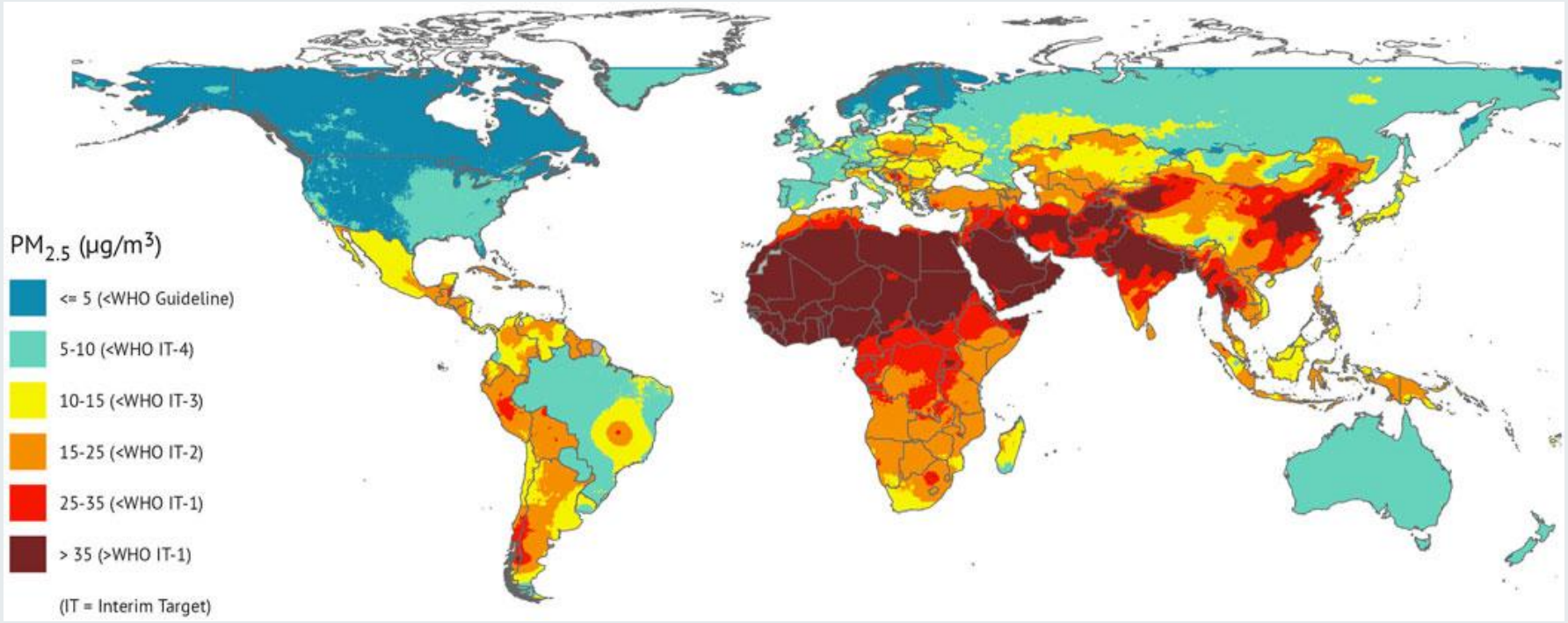
https://www.stateofglobalair.org/

* Says WHO

Last winter marked the 73th anniversary of London's Great Smog

8th December 1952 - Guardian – Trinity Mirror

Air pollution is a global health emergency*



Different types of exposure data

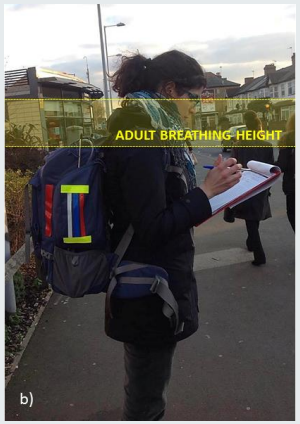
Classifying and comparing measurement techniques

	Continuous & Automatic	Semi-continious	Passive
Cost	High £5K-£200K	Medium (<£20K)	Low (£5-<£50)
Time resolution	High	Medium	Low
“Accuracy”	Can be high	Can be high	Low
Ease of deployment	Low	Medium	High
Labour in the field	High	High	Variable
Expertise required	High	High	Low

Reference grade air pollution measurement

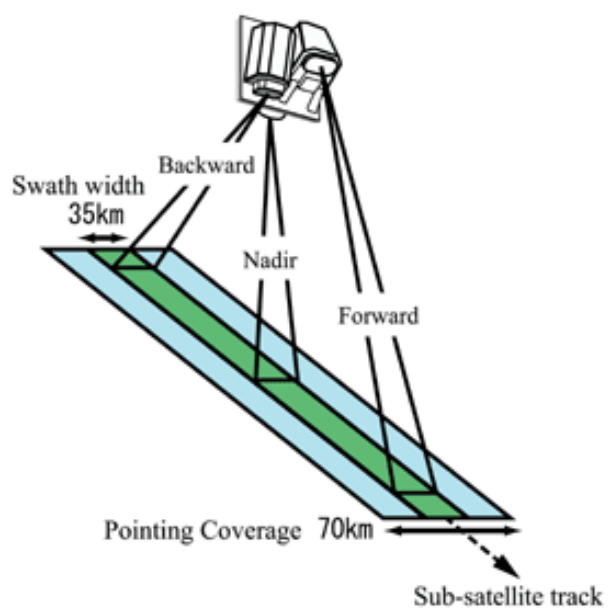
Measurement techniques -now

	Continuous & Automatic	Semi-continious	Small sensors	Passive
Cost	High £5K-£200K	Medium (<£20K)	*Low to medium (£100 - £5,000)*	Low (£5-<£50)
Time resolution	High	Medium	*High*	Low
"Accuracy"	Can be high	Can be high	*Unknown*	Low
Ease of deployment	Low	Medium	*High*	High
Labour in the field	High	High	*Low*	Variable
Expertise required	High	High	*Low to high*	Low

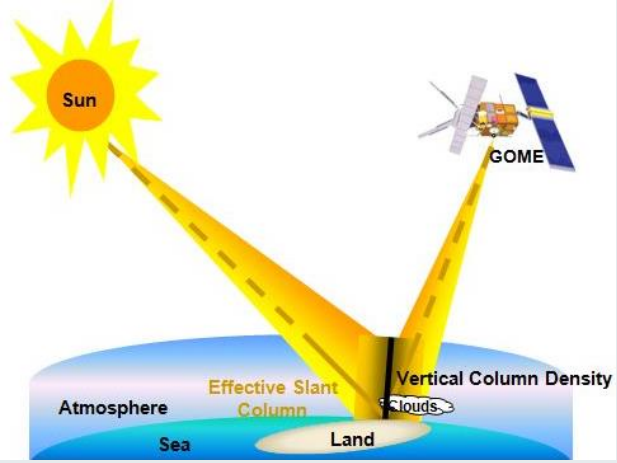


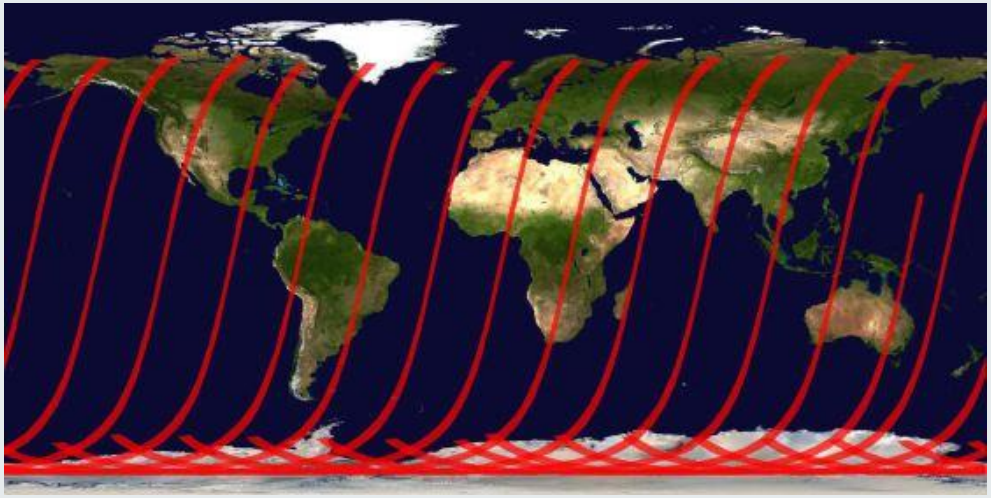
Direct calibration of small sensors is not really possible so co-location is essential

Satellite measurements



- Measurements of air pollution in the "column" beneath – this needs lots of processing to estimate concentrations at ground-level
- The area of the Earth that the satellite sees "below" it is called **swath**.
- Swath varies **10-100 km wide**.
- This are not point measurements.





Red sun phenomenon 'caused by Hurricane Ophelia'

16 October 2017 | England

PA/DOMINIC LIPINSKI

Central London was one of many parts to witness the phenomenon

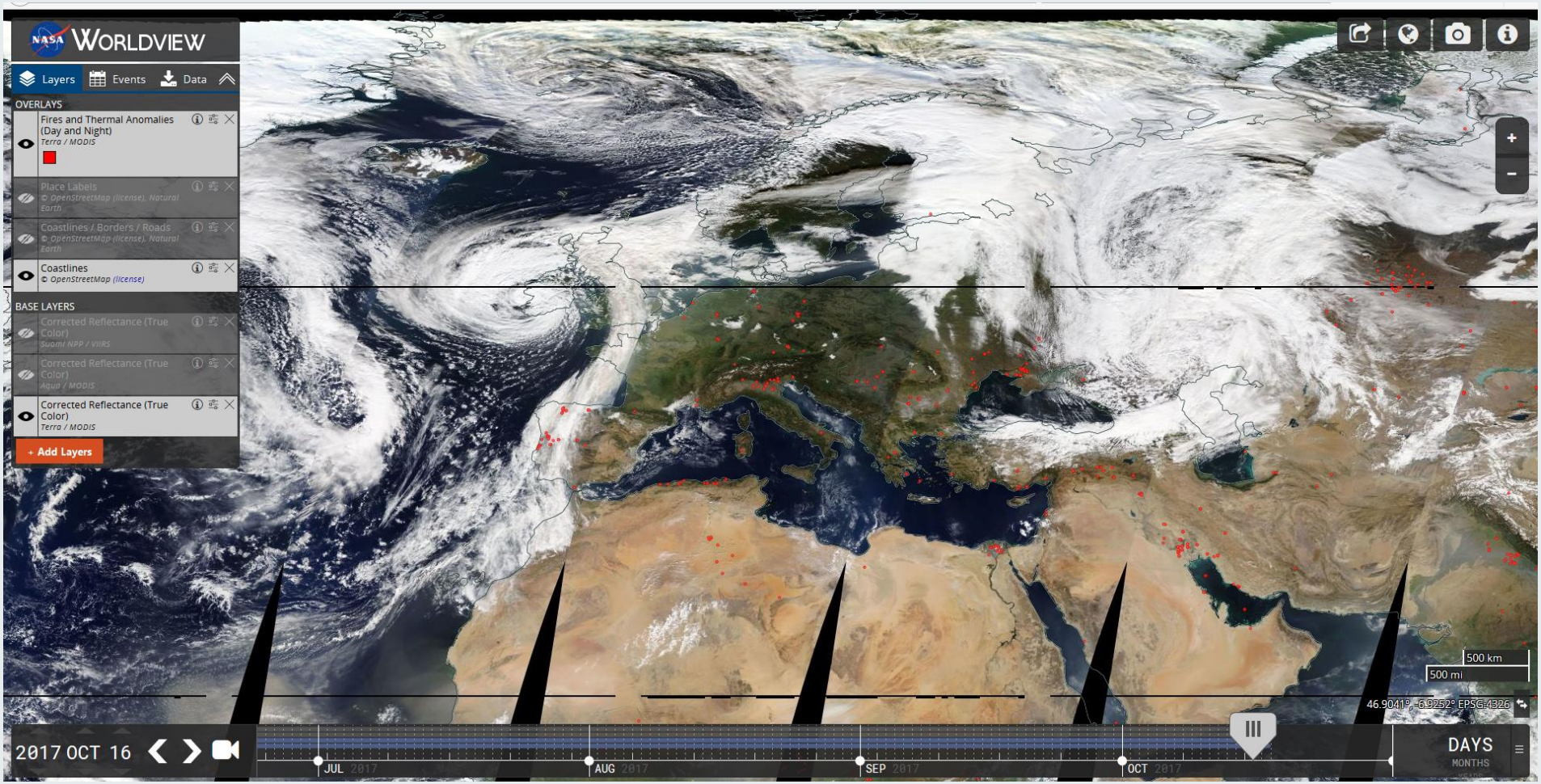
An "unusual" reddish sky and red-looking sun have been reported across many parts of England.

The phenomenon was initially seen in the west of England and Wales before spreading to other areas.

BBC weather presenter Simon King said it was due to the remnants of Hurricane Ophelia dragging in tropical air and dust from the Sahara.

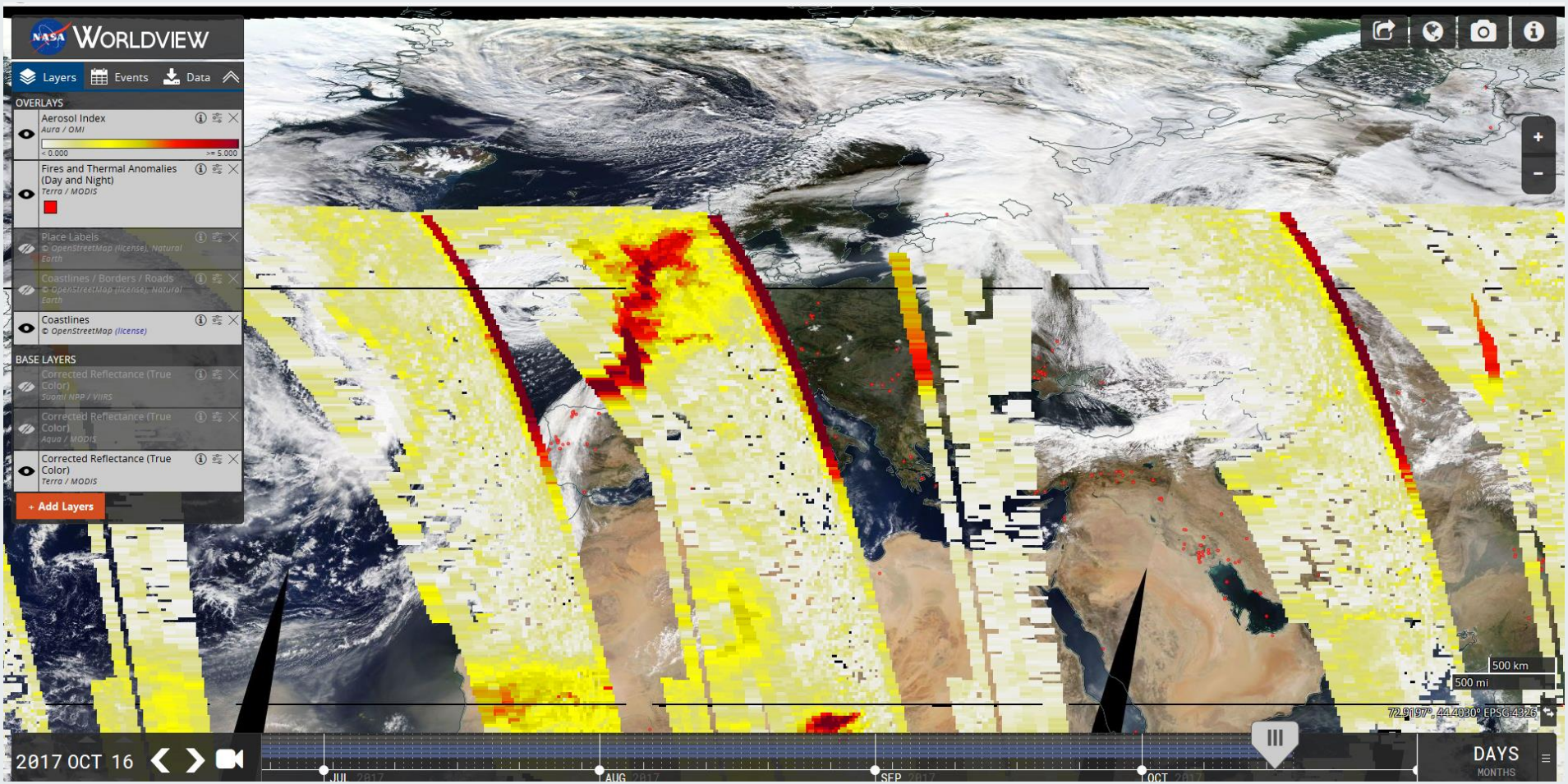
16th October 2017

https://worldview.earthdata.nasa.gov/
Fire and thermal anomalies (Terra/MODIS)



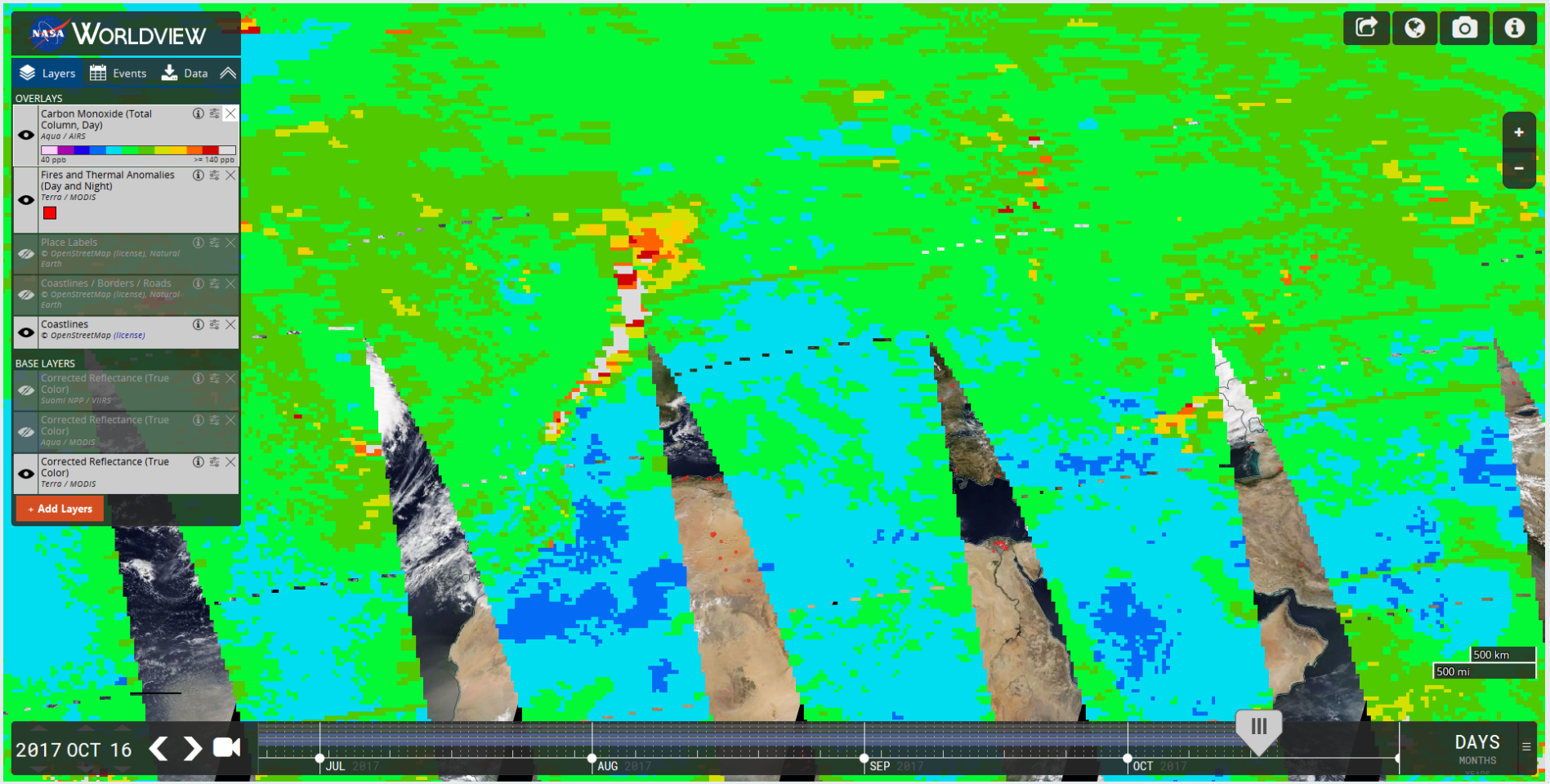
16th October 2017

Aerosol Index (OMI/Aqua): Indicates the presence of UV-absorbing aerosols (from reflectances measured by OMI at 354 and 388 nm)



16th October 2017

Carbon Monoxide (CO) Total Column (Day) (Aqua/AIRS)



Air pollution models

We cannot measure everywhere.

Although some studies use a central monitoring site as an exposure for everyone in an area, this does not allow us to explore contrasting spatial exposures in a city.

Models can predict air pollution at more places.

Most models produce a concentration in a grid area and not a point like measurements.

There are two types of model.

Land use regression

INT. J. GEOGRAPHICAL INFORMATION SCIENCE, 1997, VOL. 11, NO. 7, 699–718

Research Article

Mapping urban air pollution using GIS: a regression-based approach

DAVID J. BRIGGS[1], SUSAN COLLINS[2], PAUL ELLIOTT[3], PAUL FISCHER[5], SIMON KINGHAM[4], ERIK LEBRET[5], KAREL PRYL[6], HANS VAN REEUWIJK[5], KIRSTY SMALLBONE[7] and ANDRE VAN DER VEEN[5]

Make spot measurements across a city.

Create regression relationships between measurements and land-use variables.

Computationally simple and does not require emissions data.

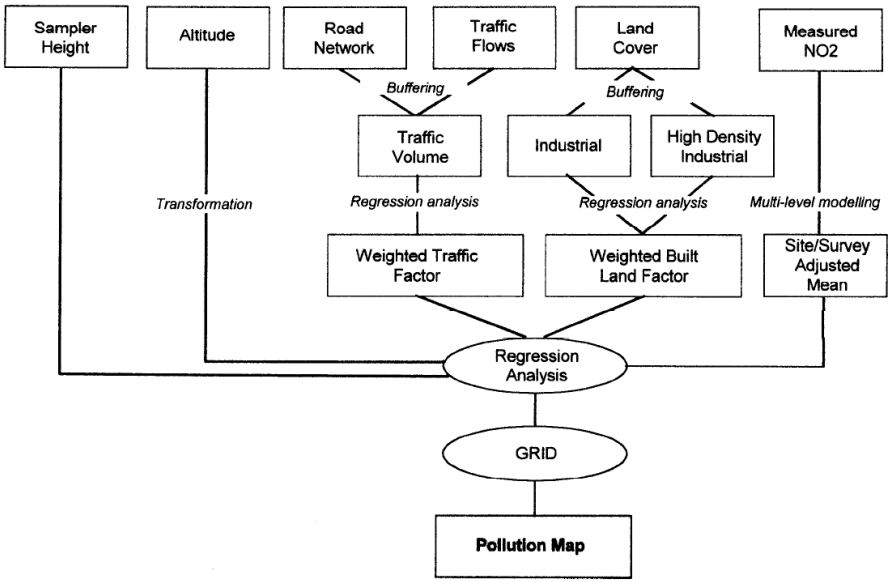


Figure 3. The regression mapping method: Huddersfield, UK.

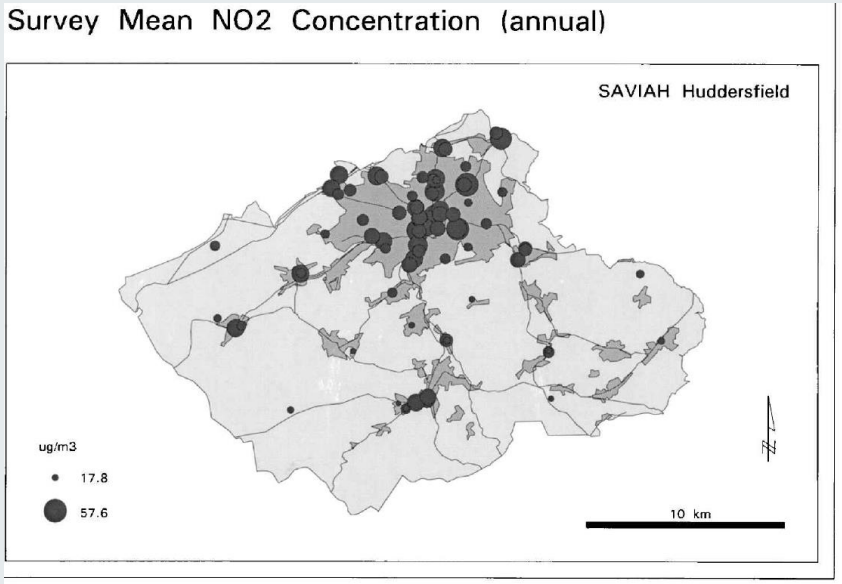
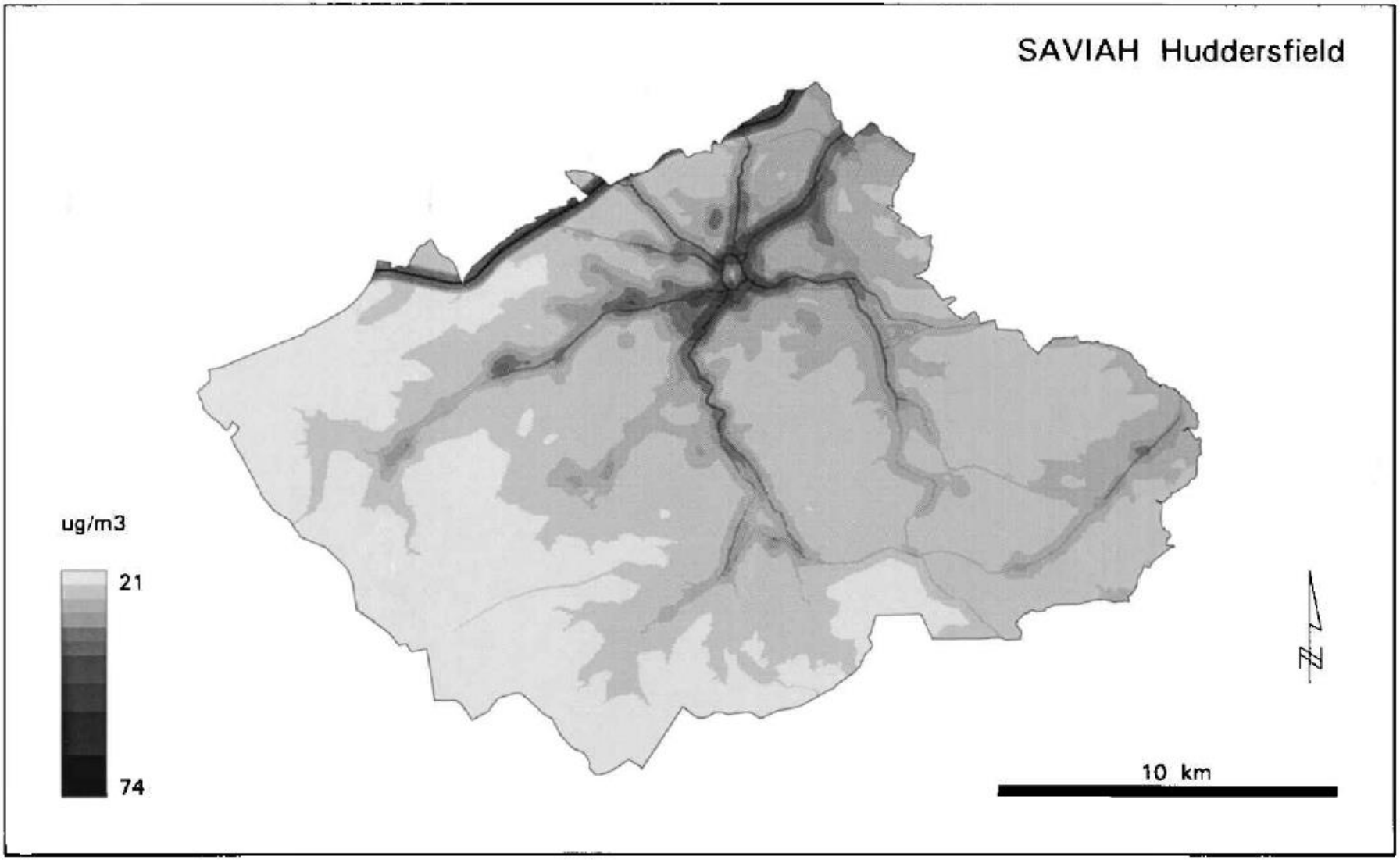


Figure 1. Monitoring results: mean annual NO_2 concentration, Huddersfield, UK.

Modelled Mean NO2 Concentration (annual)

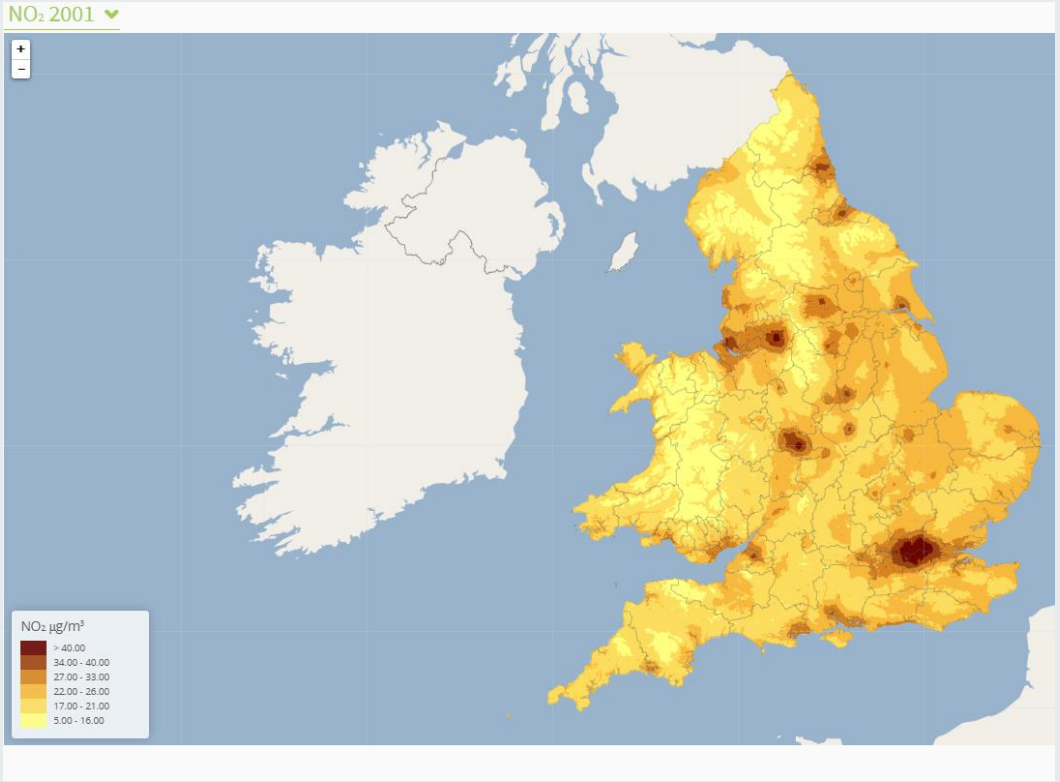
Regression Analysis

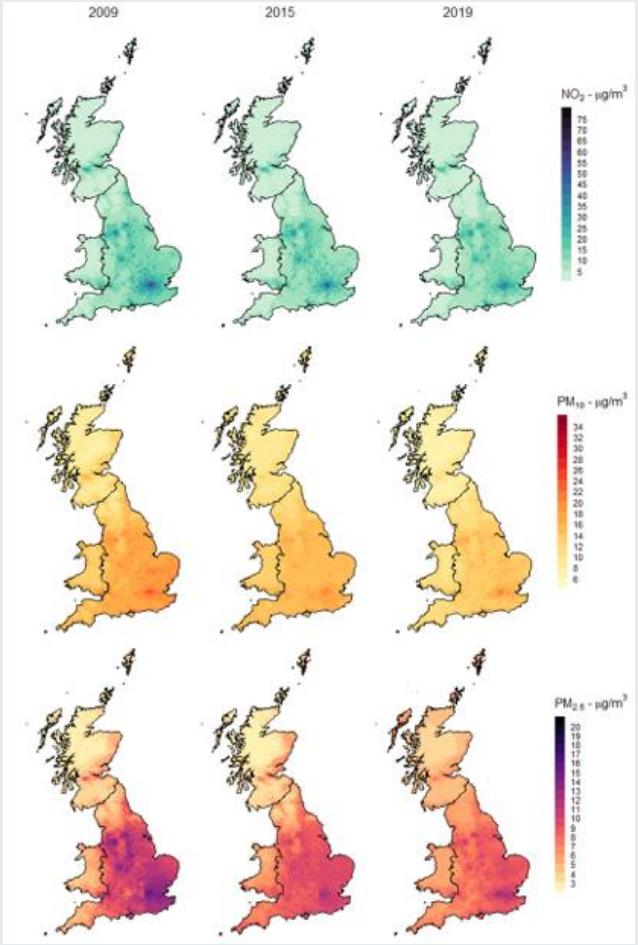


Land use regression

(left) Environment and Health Atlas - https://www.envhealthatlas.co.uk/homepage/project.html

and (right) more recently with machine learning: de la Cruz Libardi et al. 2024
https://www.sciencedirect.com/science/article/pii/S1309104224002496?via%3Dihub





Dispersion modelling

Requires details of emission sources.
Computationally and skills intense!

(CERC, ERG-Imperial College London

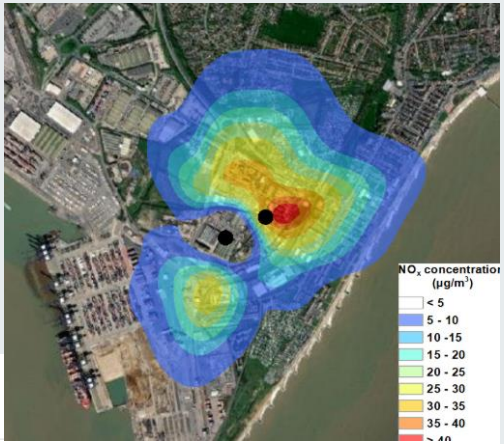
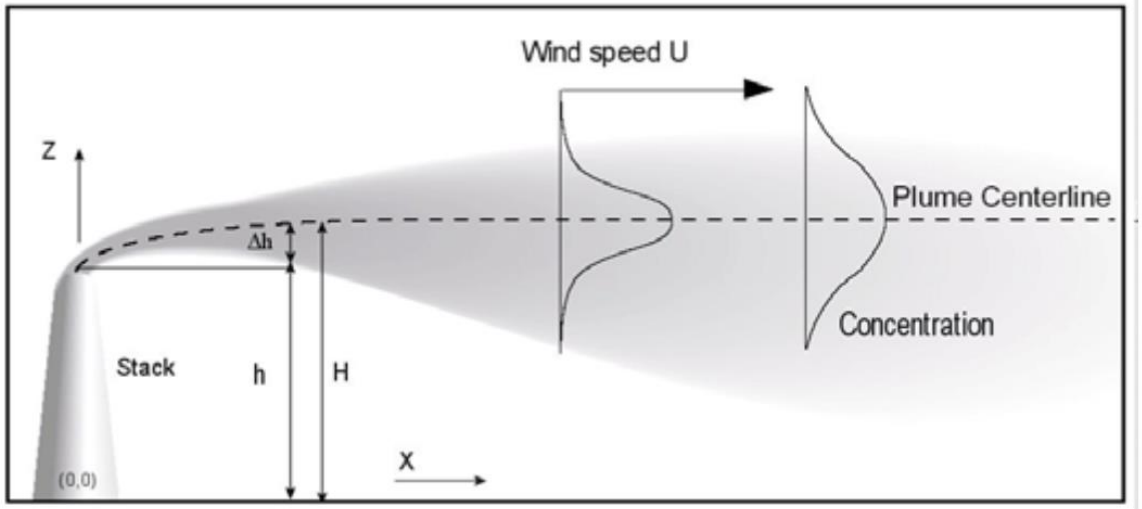
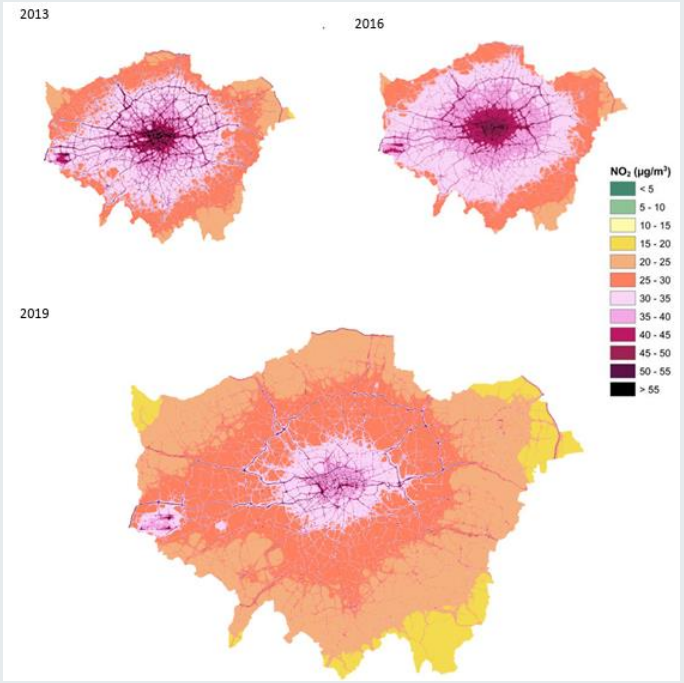


Fig 1 - uploaded by Ayman Mohamed





Corelation

Corelation between pollutants

One source often produces more that one pollutant and we are not exposed to one pollutant at a time.

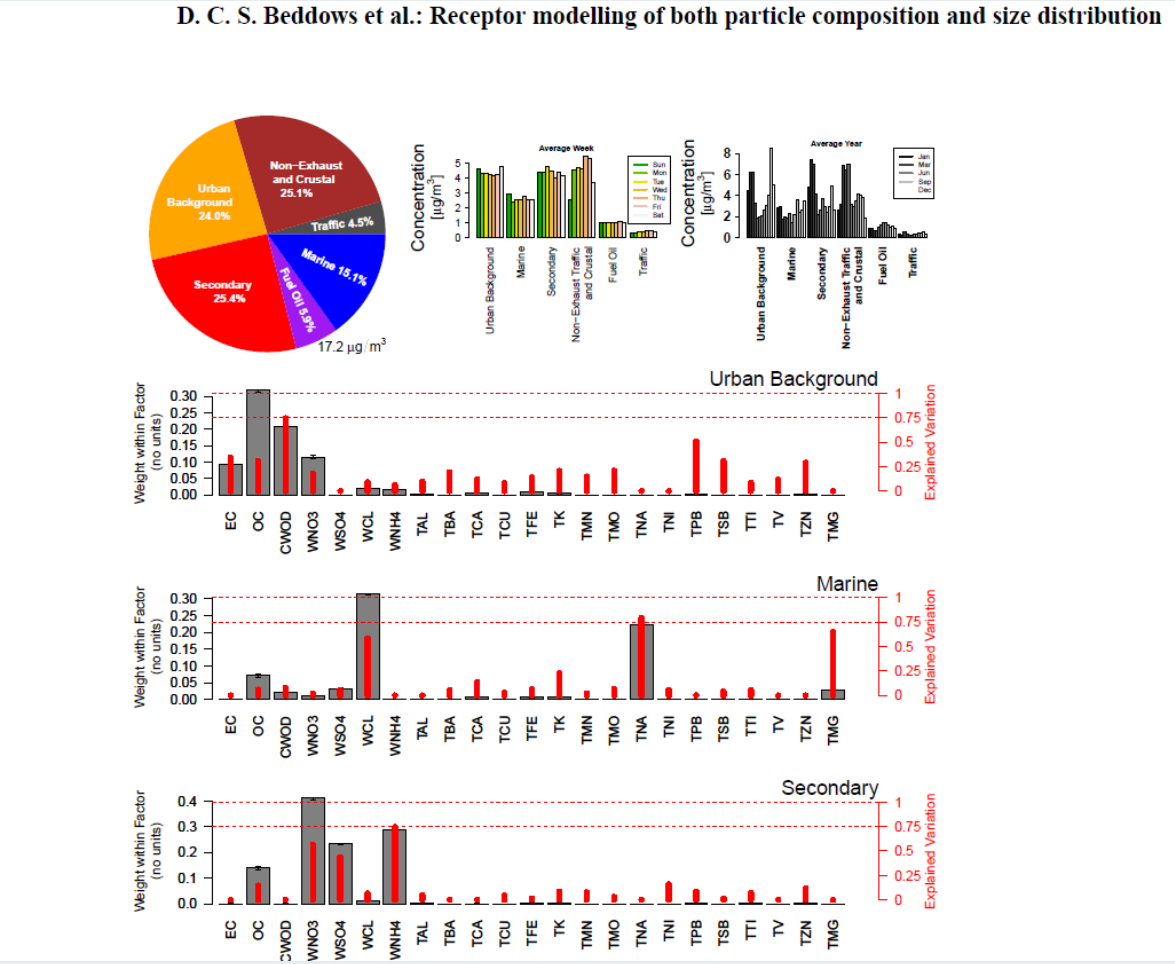
Also, primary pollutants in an area can be subject to the same weather leading to temporal corelation.

	Spearman Correlation Coefficient			
	England-wide sample			
	NO_2	PM_{10}	$PM_{2.5}$	Ozone
NO_2				
PM_{10}	0.53			
$PM_{2.5}$	0.85	0.70		
Ozone	-0.89	-0.43	-0.79	
	London-wide sample			
NO_2				
PM_{10}	0.90			
$PM_{2.5}$	0.91	0.96		
Ozone	-0.74	-0.70	-0.71	

Corelation between pollutants

One source often produces more that one pollutant.

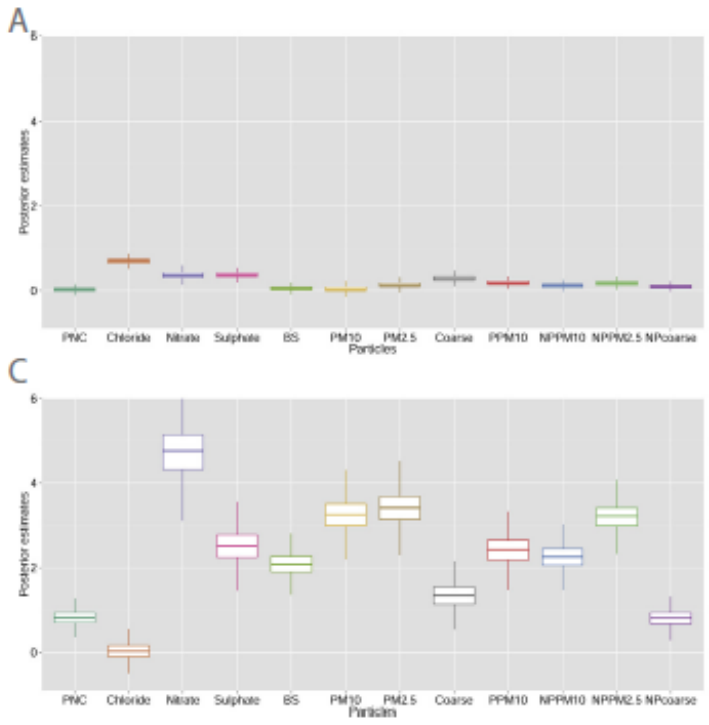
Can be used to identify sources ie by primary matrix factorisation.



Exposure to mixtures

Table 2
Correlation between pairs of airborne particle metrics. London, 2002–2005.

	PNC	Chloride	Nitrate	Sulphate	BS	PM_{10}	$PM_{2.5}$	Coarse	PPM_{10}	$NPPM_{10}$	$NPPM_{2.5}$	NPcoarse
PNC												
Chloride	0.34											
Nitrate	0.38	−0.17										
Sulphate	0.08	−0.31	0.52									
BS	0.49	−0.16	0.46	0.35								
PM_{10}	0.30	−0.16	0.67	0.66	0.48							
$PM_{2.5}$	0.31	−0.29	0.70	0.68	0.51	0.91						
Coarse	0.09	0.11	0.18	0.25	0.13	0.57	0.26					
PPM_{10}	0.72	−0.09	0.53	0.30	0.74	0.53	0.56	0.15				
$NPPM_{10}$	−0.12	−0.16	0.43	0.55	0.20	0.68	0.60	0.49	0.11			
$NPPM_{2.5}$	−0.16	−0.39	0.48	0.68	0.28	0.67	0.68	0.31	0.14	0.86		
NPcoarse	0.02	0.22	0.21	0.15	0.03	0.43	0.25	0.56	0.06	0.71	0.31	




Environment International 79 (2015) 56–64

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Analysing the health effects of simultaneous exposure to physical and chemical properties of airborne particles

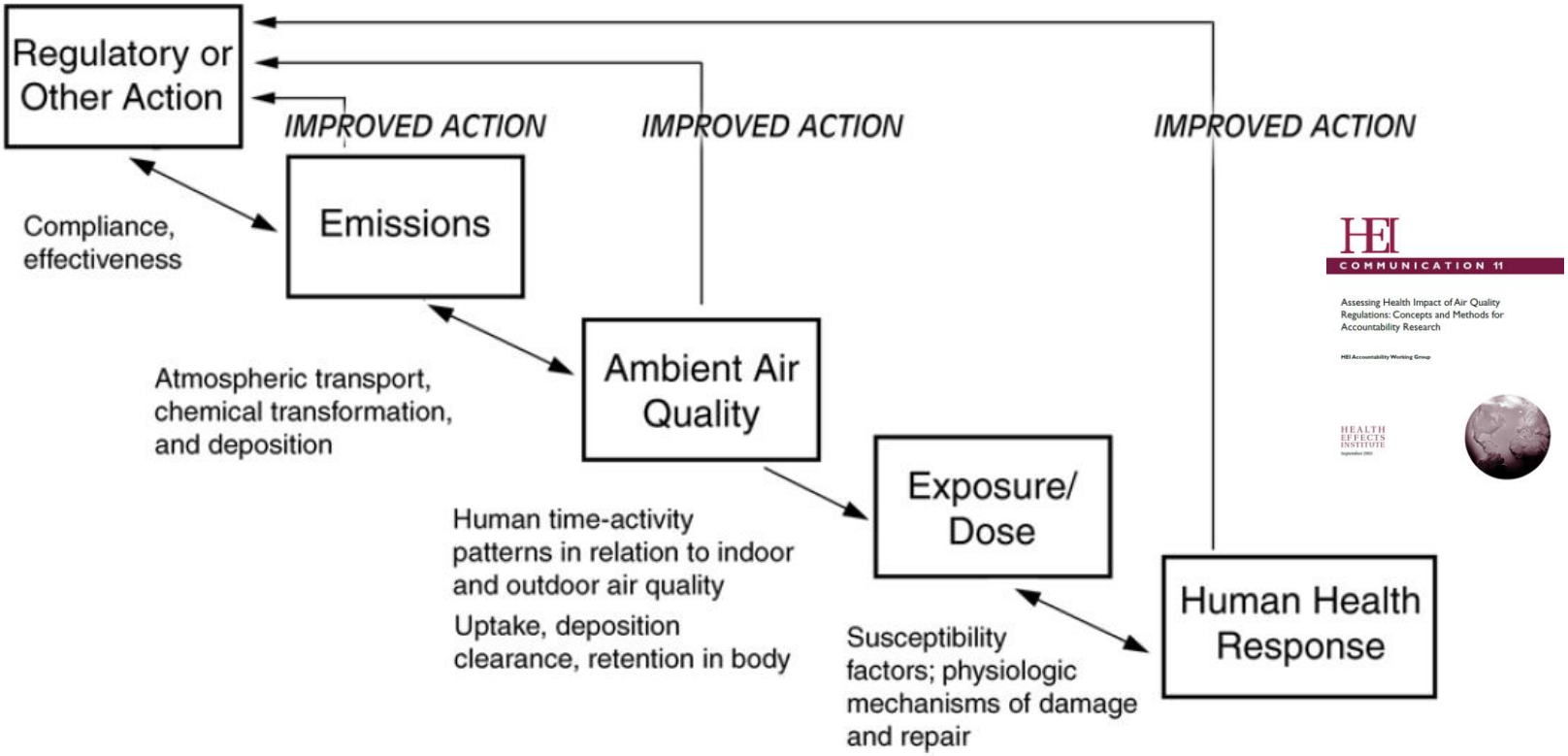
Monica Pirani [a,*], Nicky Best [b], Marta Blangiardo [b], Silvia Liverani [c,d,e], Richard W. Atkinson [f], Gary W. Fuller [a]

[a] MRC-PHE Centre for Environment and Health, King's College London, Division of Analytical and Environmental Science, Franklin-Wilkins Building, 150 Stamford Street, SE1 9NH, London, UK
[b] MRC-PHE Centre for Environment and Health, Imperial College London, Department of Epidemiology and Biostatistics, S26 Norfolk Place, W2 1PG London, UK
[c] Brunel University, Department of Mathematics, UB8 3PH Uxbridge, London, UK
[d] MRC Biostatistics Unit, Institute of Public Health, Forvie site, Robinson Way, CB2 0SR Cambridge, UK
[e] Imperial College London, Department of Epidemiology and Biostatistics, S26 Norfolk Place, London W2 1PG London, UK
[f] MRC-PHE Centre for Environment and Health, St. George's University of London, Population Health Research Institute, Cranmer Terrace, SW17 0RE London, UK

Fig. 1. Box plots showing the distribution of the posterior means for each particle component (on normalised scale) for the three clusters that form the representative clustering (A = cluster 1; B = cluster 2; C = cluster 3).

Affecting change
The “accountability” chain between pollutant sources and health

The "accountability" chain between pollutant sources and health



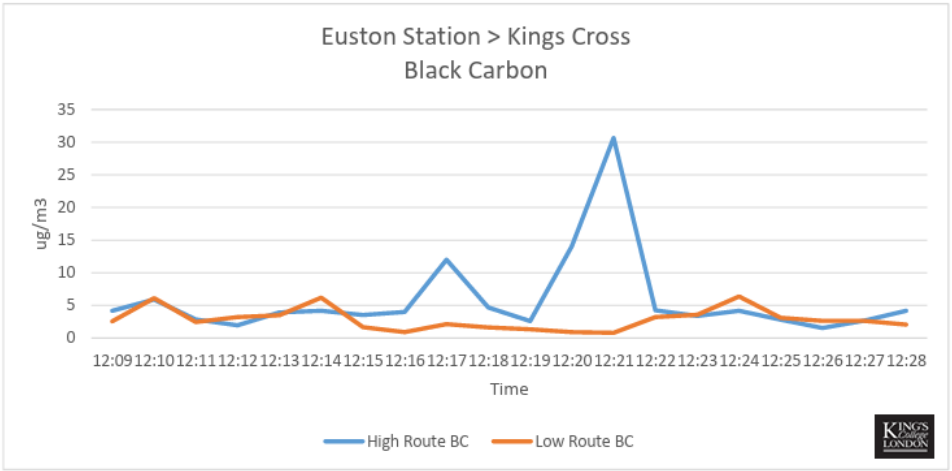
Chain of accountability. Each box represents a link between regulatory action and human health response to air pollution. Arrows connecting the links indicate possible directions of influence. Text below the arrows identifies general indices of accountability at that stage. At several stages, knowledge

	Energy	Industry	Transport	Waste	Residential	Agriculture	Windblown Dust
South Africa	22.5%	6.8%	6.5%	3.9%	16%	6.2%	8.5%
DRC	1.8%	4.4%	1.4%	1.2%	11.7%	2.2%	10.6%
Kenya	7.9%	4.6%	6.1%	2.1%	26.7%	0.5%	25.1%
Ghana	2.2%	1.2%	3.1%	0.7%	6.6%	1.8%	67.6%
Egypt	11.7%	5.3%	6.3%	5.8%	4%	5.9%	42%

Sources of PM2.5 in African countries

https://www.worldbank.org/en/news/feature/2017/03/10/nigerias-flaring-reduction-target-2020

Figure 2 Time series showing black carbon concentrations on the Euston Station > King's Cross route pair.



Pollutionwatch
Air pollution

This article is more than 1 year old

Targeting India's most harmful power plants could slash mortality

Study finds about a quarter of health burden comes from power stations that generate just 3% of country's electricity

Gary Fuller

Fri 17 May 2024 06.00 BST

Less than 5% of India's power plants have modern systems to clean up air pollutants including sulphur and mercury. Photograph: Idrees Mohammed/EPA

India struggles with some of the worst air pollution in the world. Now scientists have worked out which of the country's power plants are the worst in pollution terms, narrowing it down to 30 units which are responsible for about a quarter of the mortality burden.

Electricity generation accounts for nearly three-quarters of India's enormous coal use. But despite regulations set in 2015, less than 5% of India's power plants have modern systems to clean up air pollutants including sulphur and mercury.

The new study from Stanford University looked at the performance of the country's power plants. The lead author, Kirat Singh, said: "We wanted to see if some power plants were disproportionately driving the mortality burden. Identifying these could move the needle on improving air quality."

ENVIRONMENTAL RESEARCH
LETTERS

LETTER

Air pollution mortality from India's coal power plants: unit-level estimates for targeted policy

https://www.theguardian.com/environment/article/2024/may/17/targeting-indias-most-harmful-power-plants-could-slash-mortality

https://iopscience.iop.org/article/10.1088/1748-9326/ad472a

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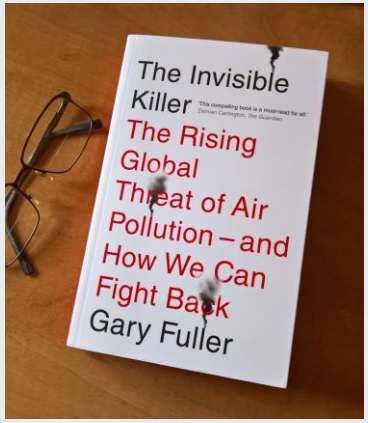
Online - June 2025



Clean Air Programme
www.ukcleanair.org/