Atmospheric Composition and Air Quality Group

Group website: https://maraisresearchgroup.co.uk/

1 February 2021

GEOG0012

Dr Eloise A Marais

What is Air Pollution?

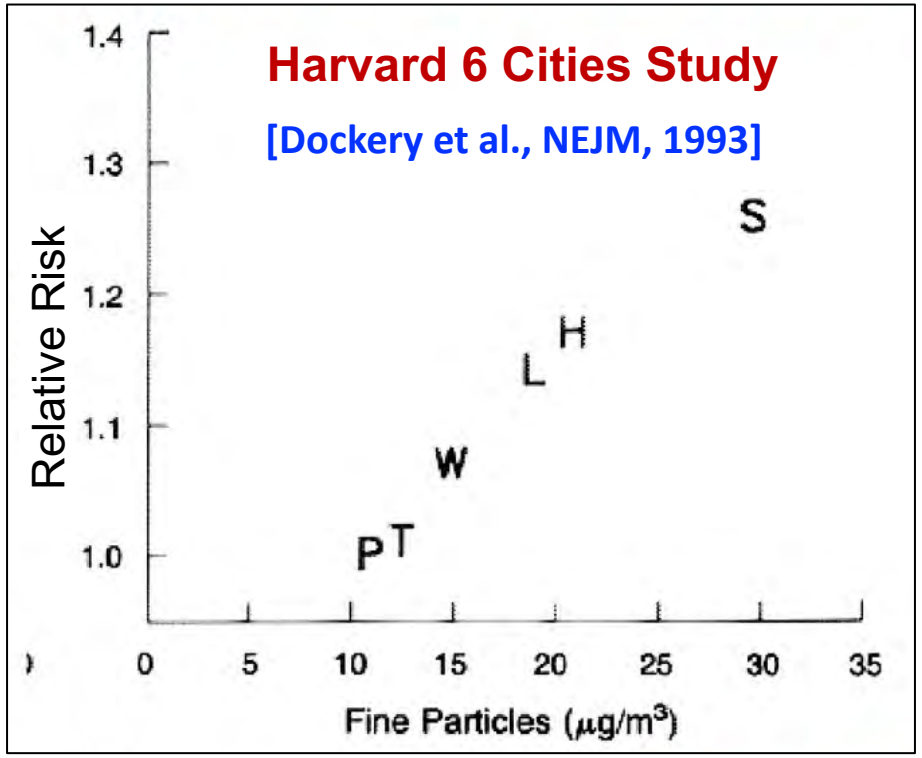
Release of gases and particles to the atmosphere that have a negative impact on our health and the built and natural environment

Many cities like Delhi experienced sustained clean air for the first time in years during COVID-19 lockdowns

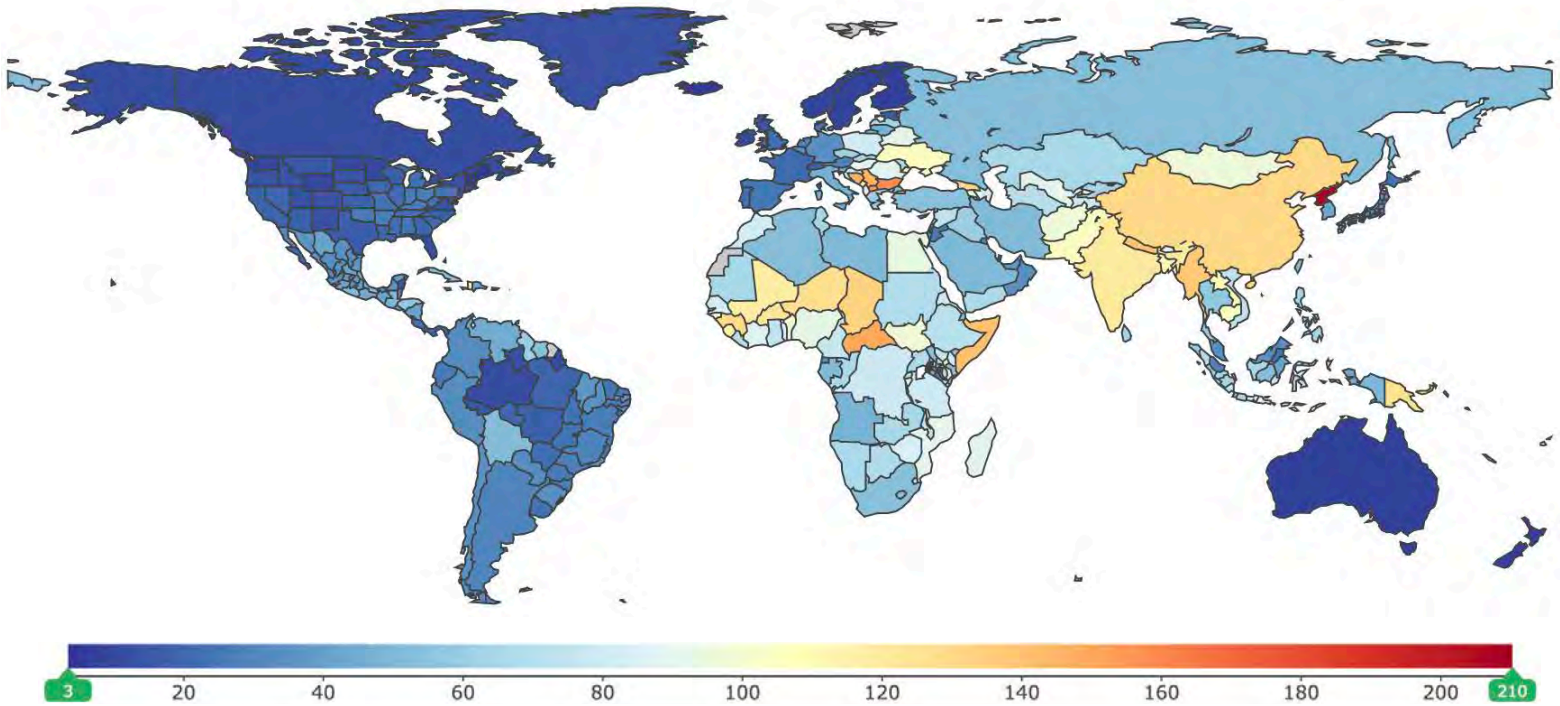
Typical Criteria Pollutants:

Benzene
Formaldehyde
Ozone (**O_3**)
Nitrogen dioxide (**NO_2**)
Fine particles (**$PM_{2.5}$**)
Carbon monoxide (**CO**)
Lead (**Pb**)
Sulfur dioxide (**SO_2**)

Hazardous Effects of Air Pollution



Death rates from exposure to air pollution (per 100,000)



[http://www.healthdata.org/gbd/data-visualizations]

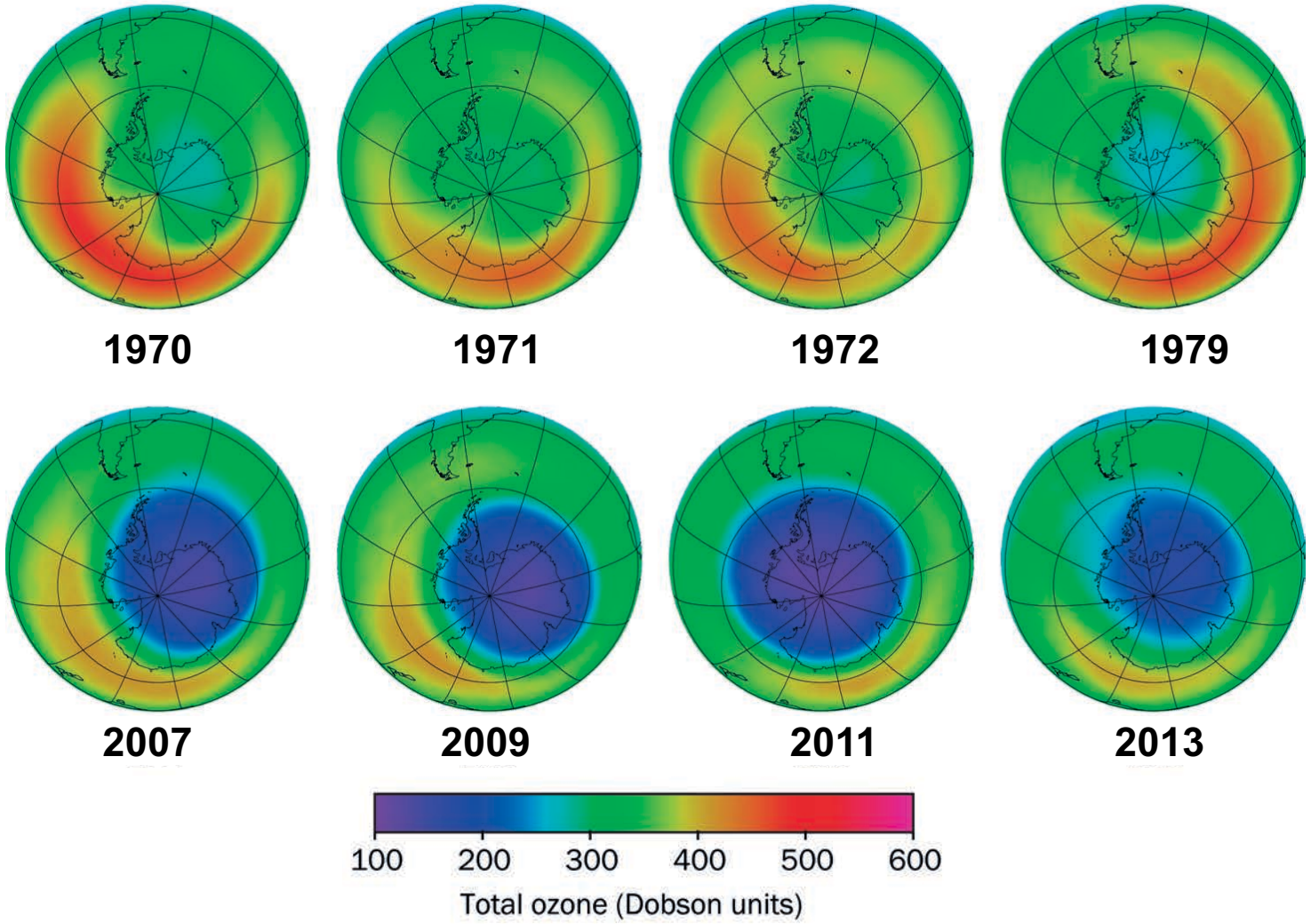
The more we study air pollution, the more we discover about its ill effects on health:

Lung cancer, respiratory disease, cognition, eyesight, dementia, diabetes, lung development, mortality

Hazardous Effects of Air Pollution

Ozone: Good Up High, Bad Nearby

Loss of Ozone in the Stratosphere (>10 km altitude) over Antarctica



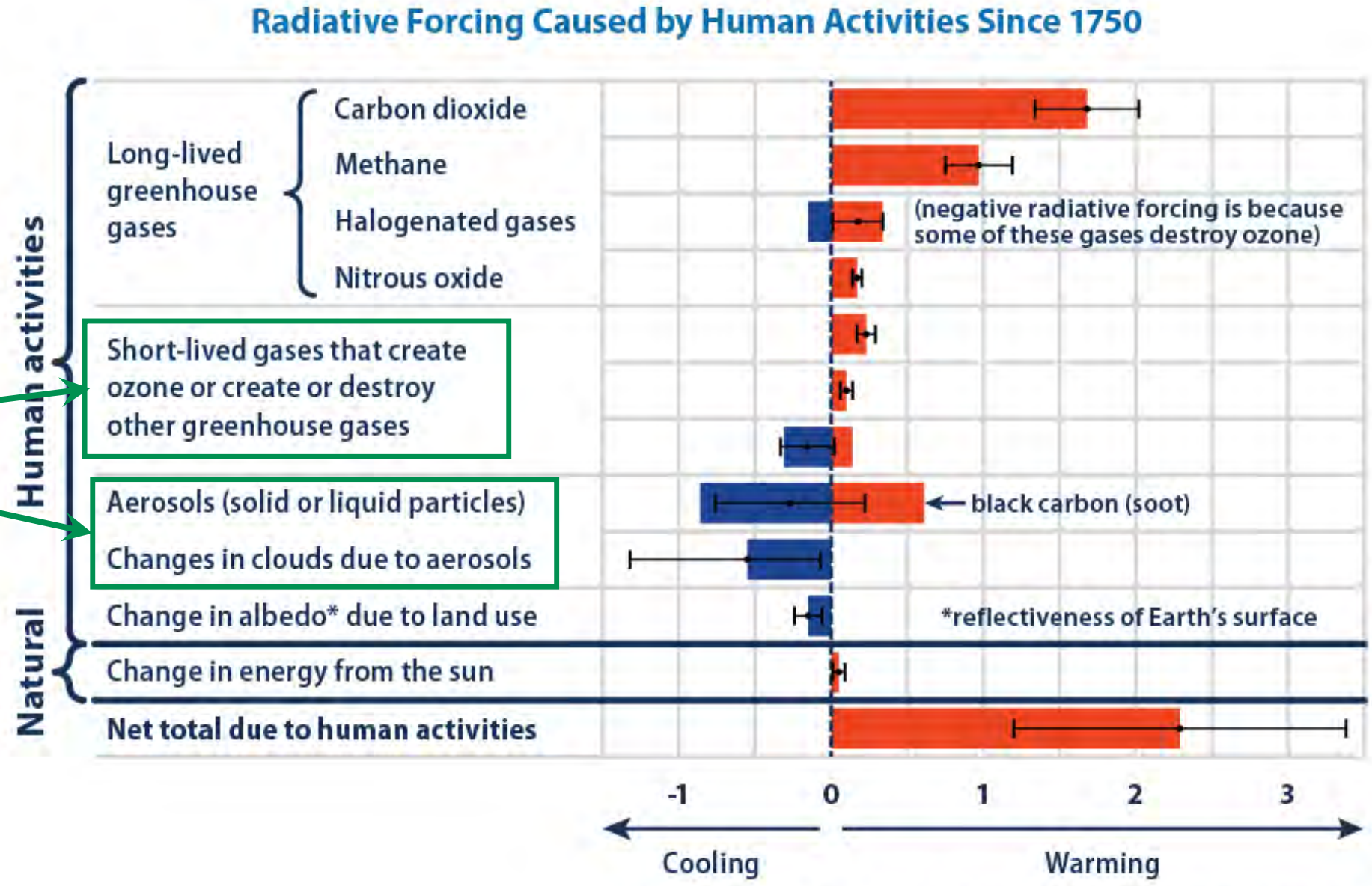
[https://climate.nasa.gov/internal_resources/1916/]

Surface Ozone Damage to Plants

Concern for crop yields, food security, economic losses, ecosystem services (reliance on vegetation for livelihood and/or wellbeing)

Hazardous Effects of Air Pollution

Climate effect of air pollutants (or short-lived climate forcers)



[https://www.epa.gov/climate-indicators/climate-change-indicators-climate-forcing]

Public Concern over Air Pollution

Air pollution is in the public consciousness, as indicated by routine reporting in leading newspapers

January 2021

The long read / Cash injection: could we cure all disease with a trillion dollars?

The long read: Could such a large amount of money end the Covid pandemic? Eradicate disease? Provide universal healthcare and fund vaccine research?

28 Jan 2021

UK mayors urge Boris Johnson to commit to tougher air pollution targets

27 Jan 2021

Air pollution linked to higher risk of irreversible sight loss

26 Jan 2021

The Guardian view on electric cars: greener roads are good

22 Jan 2021 167

California has environmental allies once again with Biden in the White House

21 Jan 2021

Limiting air pollution 'could prevent 50,000 deaths in Europe'

20 Jan 2021

Wildfires having devastating effect on air quality in western US, study finds

19 Jan 2021

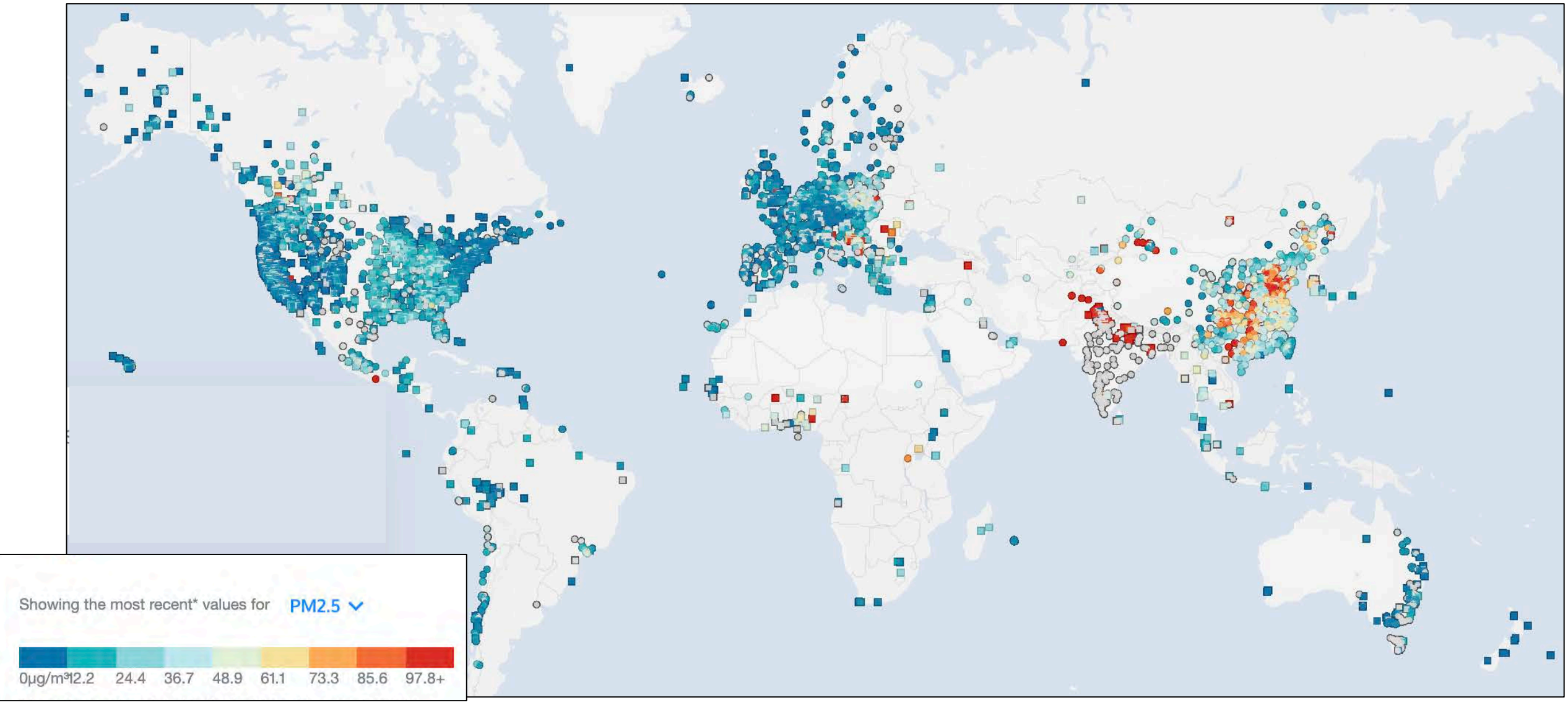
Air pollution will lead to mass migration, say experts after landmark ruling

Pollutionwatch / Pollutionwatch: major sources of air pollution often overlooked

[https://www.theguardian.com/environment/air-pollution]

Ongoing Research is Vital

Large data and knowledge gaps in rapidly developing countries with unenforced air quality policy

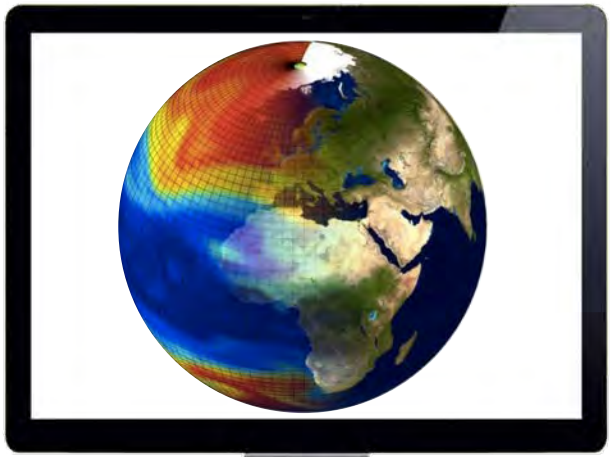


[https://openaq.org/#/map]

UCL Geography Air Pollution Research

The tools we use and develop to address uncertainties and inform policy.

CHAMBER



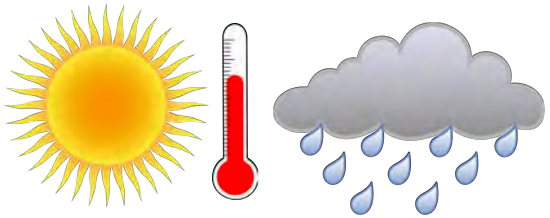
3D ATMOSPHERIC CHEMISTRY MODEL

SATELLITES

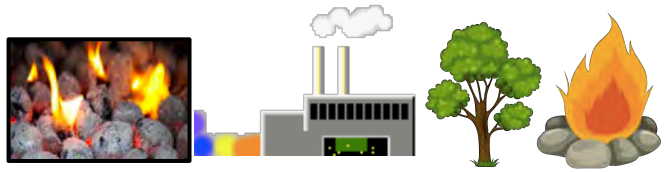
IN SITU

UCL Geography Air Pollution Research

Model: computer code to represent our best understanding of atmospheric chemistry in 3D

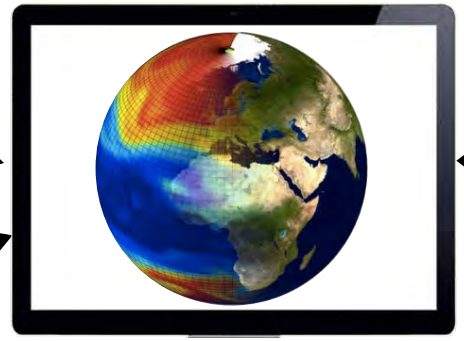


Meteorology



Emissions (natural/human)
(***includes temporal variability***)

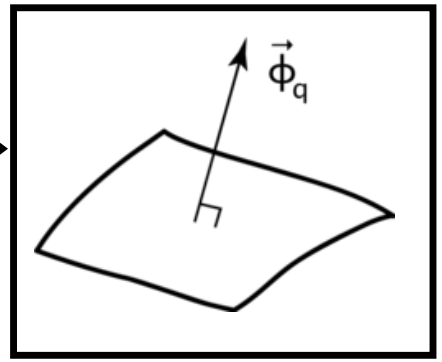
3D MODEL



Chemistry
Transport
Dry/wet deposition

Calculates impacts on **air pollution**

Radiative Transfer Model



Energy budget

Calculates impacts on **climate**

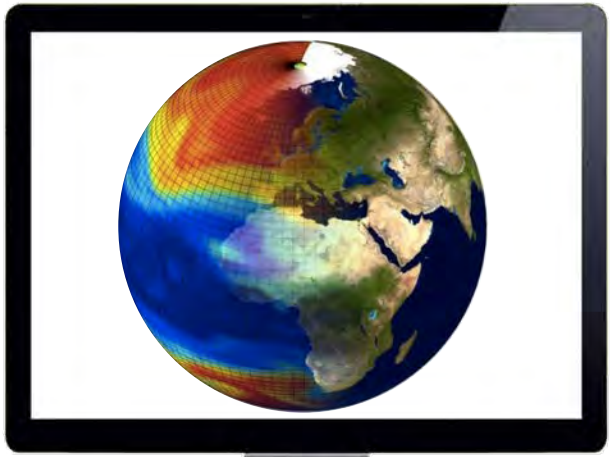
To find out more about GEOS-Chem: http://acmg.seas.harvard.edu/geos/index.html

UCL Geography Air Pollution Research

Observations:

improve and validate models, but models also help us interpret the observations

CHAMBER



3D ATMOSPHERIC CHEMISTRY MODEL

SATELLITES

IN SITU

The Skills Gained from Computational Air Pollution Research

- Fundamental knowledge of atmospheric chemistry and air quality
- Data management, analysis, and visualization
- Computer programming
- Written and spoken science communication
- Organizational skills required of any professional setting: time management, team work, networking

These Skills are Valued in Multiple Sectors

- Data scientist (highly sought after)
- Research
- Education
- Environment
- Policy
- Energy, Industry, Transport

Take a look at the range of careers of alumni from the group where I obtained my PhD:
http://acmg.seas.harvard.edu/alumni_list.html

Before We Proceed

Below are examples of research by other groups and institutions that have contributed to discovering and addressing issues related to air pollution

(1) VW Emissions Scandal

News article: https://www.npr.org/2015/09/24/443053672/how-a-little-lab-in-west-virginia-caught-volkswagens-big-cheat

(2) Effect of air pollution on our brains

TED talk: https://www.ted.com/talks/maria_neira_this_is_your_brain_on_air_pollution?language=en
Dr Neira is Director of the Public Health, Environment and Social Determinants of Health Department (PHE) of the World Health Organization (WHO). More about her here: https://en.wikipedia.org/wiki/Maria_Neira

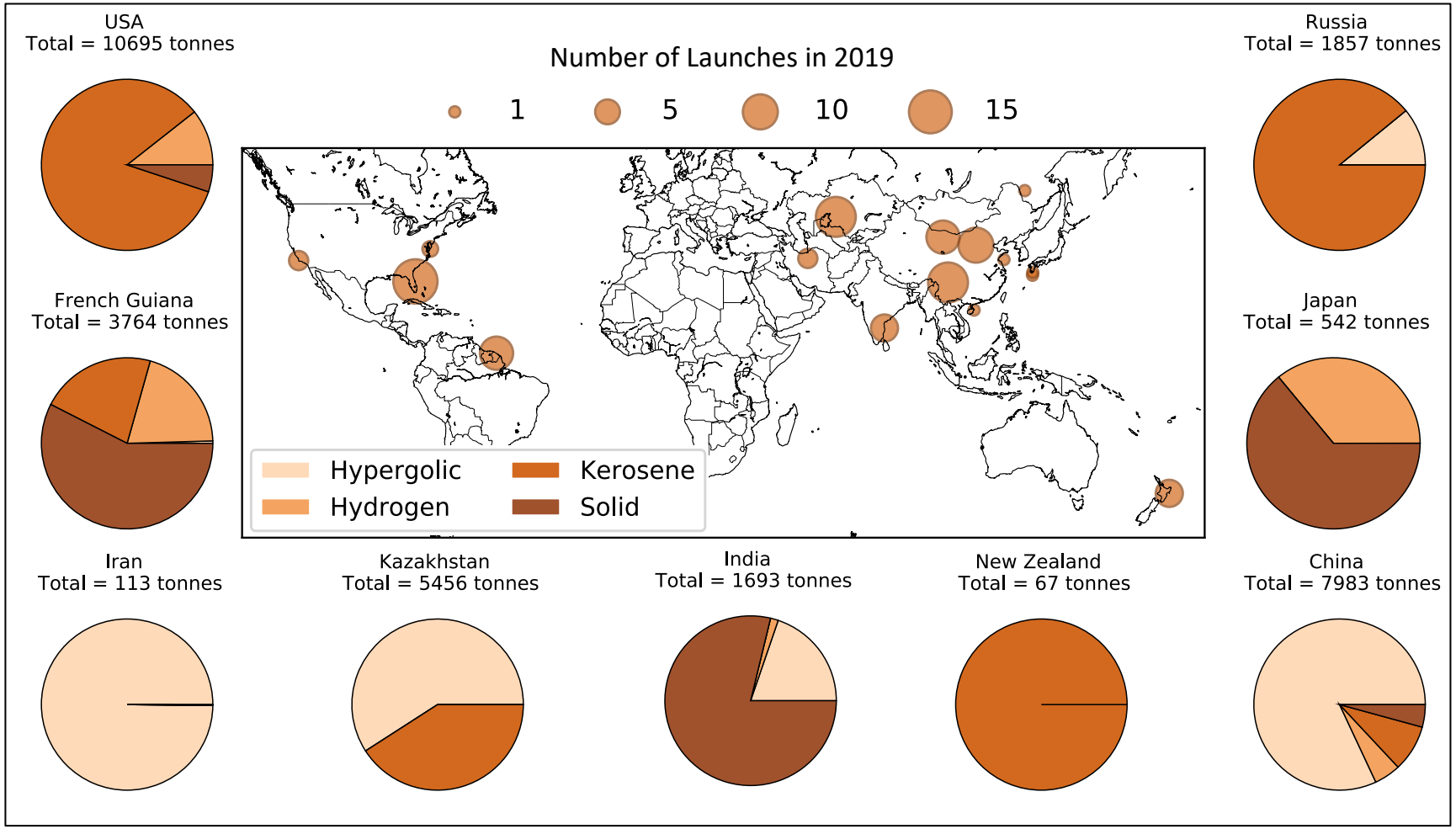
(3) Interdisciplinary approach to tackle air pollution in India

Podcast: https://soundcloud.com/world-resources-institute/wri-podcast-29-air-quality-with-jessica-seddon

Recent and Current Research Projects in the UCL Atmospheric Chemistry and Air Quality Group

Rockets and Air Pollution

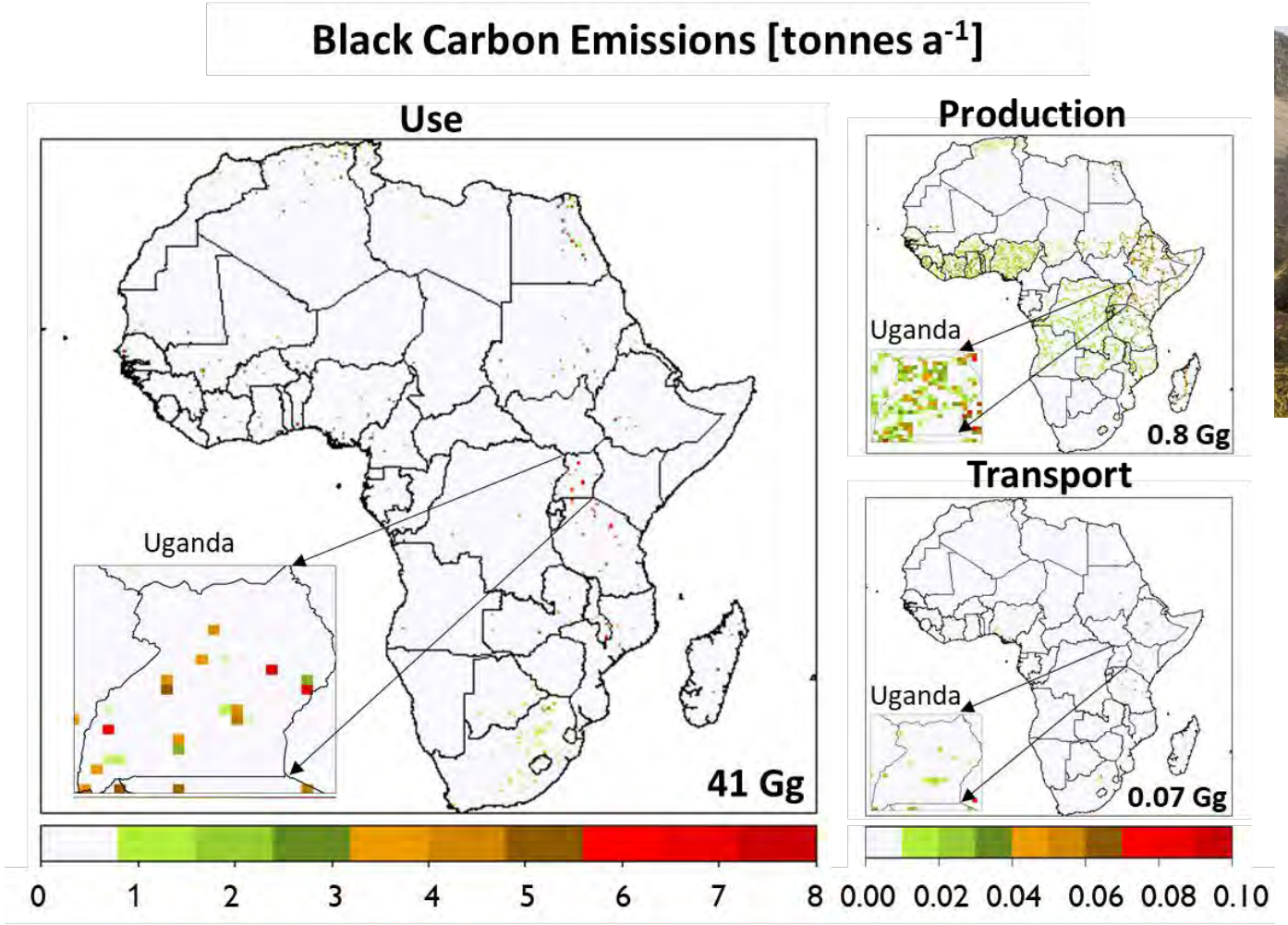
The space sector is growing rapidly. Fuels used include chemicals that deplete stratospheric ozone.



What is the contribution of rocket fuel and returning space junk to ozone loss in the stratosphere?

The Burgeoning Charcoal Industry in Africa

Charcoal production increases at 7% per year, but most research has focused on deforestation



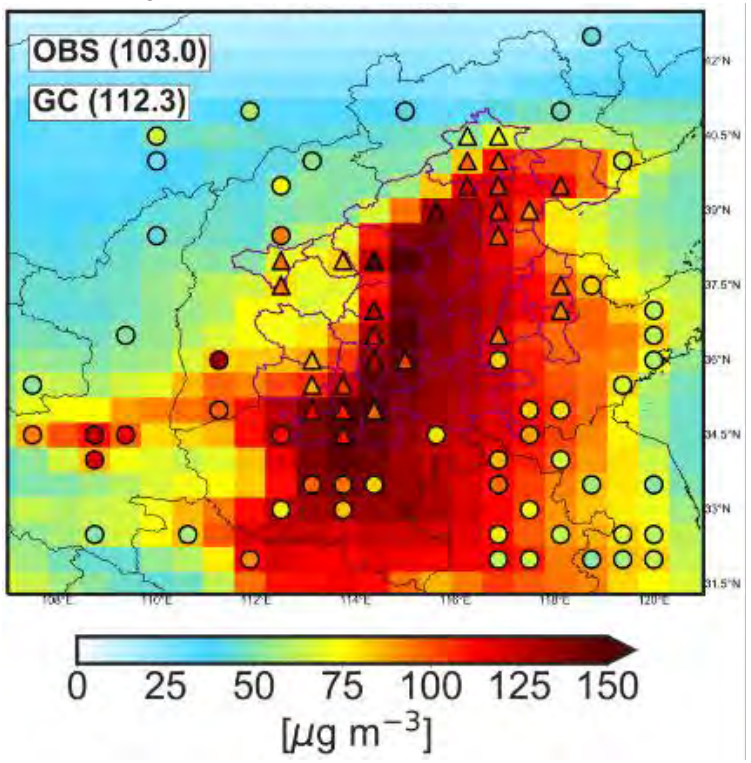
We quantified the impact of emissions from this industry on air quality and short-term climate to incentivize the transition to renewable energy

[Bockarie et al., 2019, doi:10.1021/acs.est.0c03754]

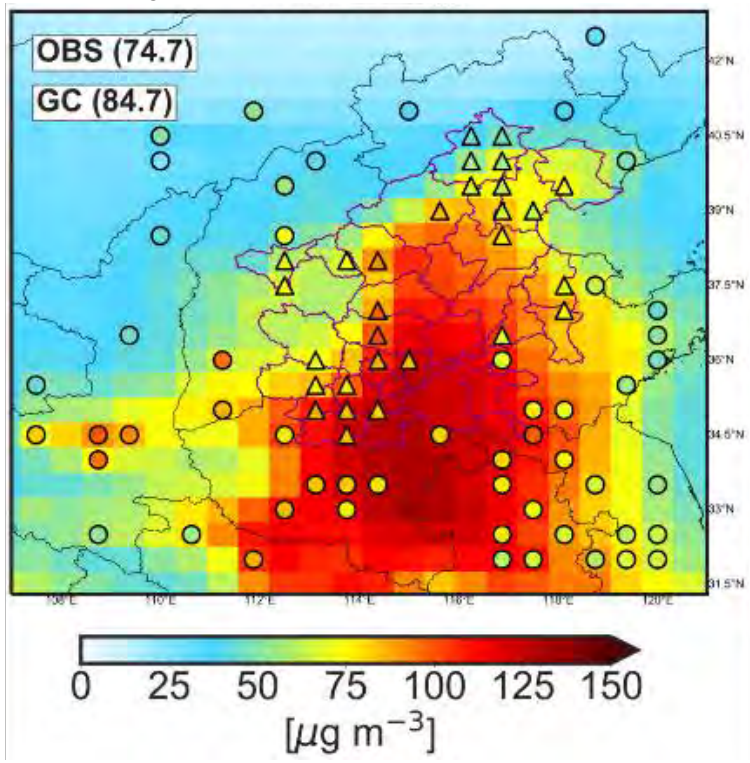
Efficacy of Strict Air Quality Measures in Northern China

Strict emission controls enacted in the Beijing-Tianjin-Hebei region to address severe air pollution

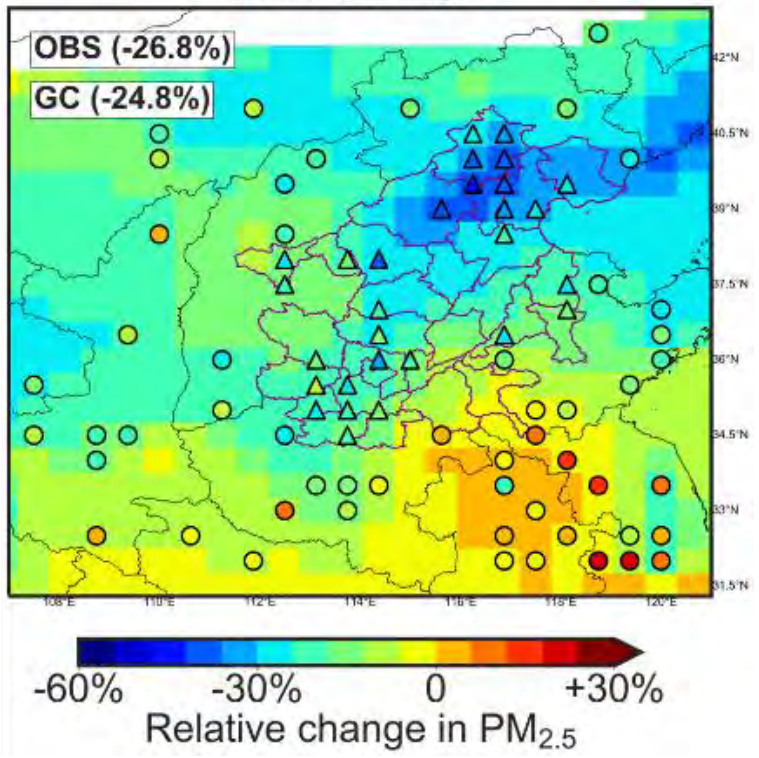
$PM_{2.5}$ in Autumn-Winter 2016



$PM_{2.5}$ in Autumn-Winter 2017



2017 relative to 2016



BTH regional mean $PM_{2.5}$ of 75-110 μg m^{-3} far exceed the WHO guideline of 10 μg m^{-3}

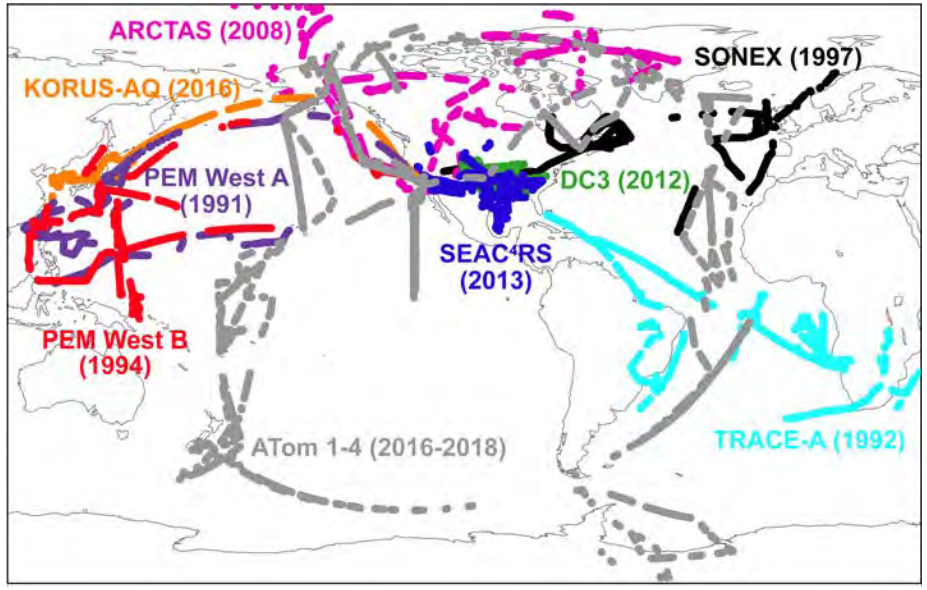
$PM_{2.5}$ decreases by ~25%, but we find that this not only due to emission controls, but also meteorology

New Data Products from Instruments in Space

Address monitoring gaps and data deficiencies in the global upper troposphere (8-12 km overhead)

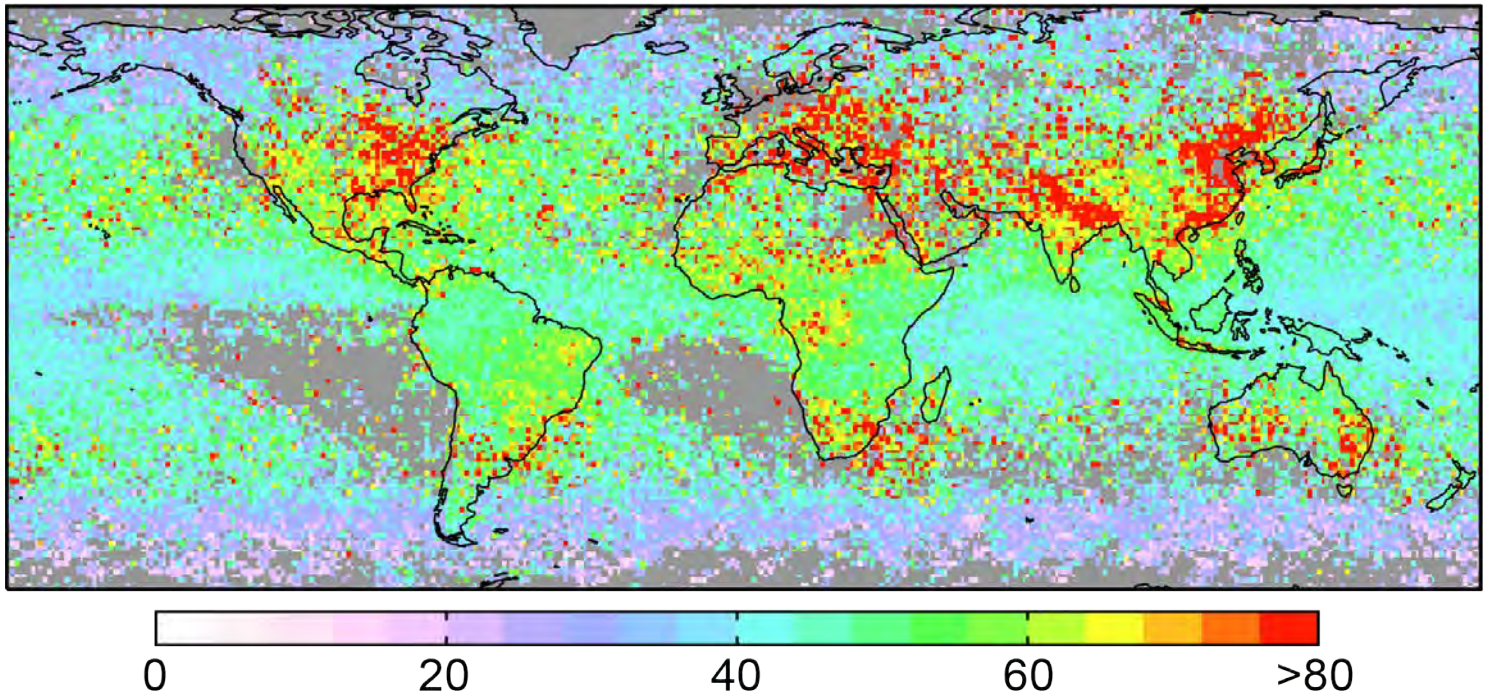
In the upper troposphere ozone is a potent greenhouse gas

Very few measurements from research and commercial aircraft



Global coverage with a new product developed in my group

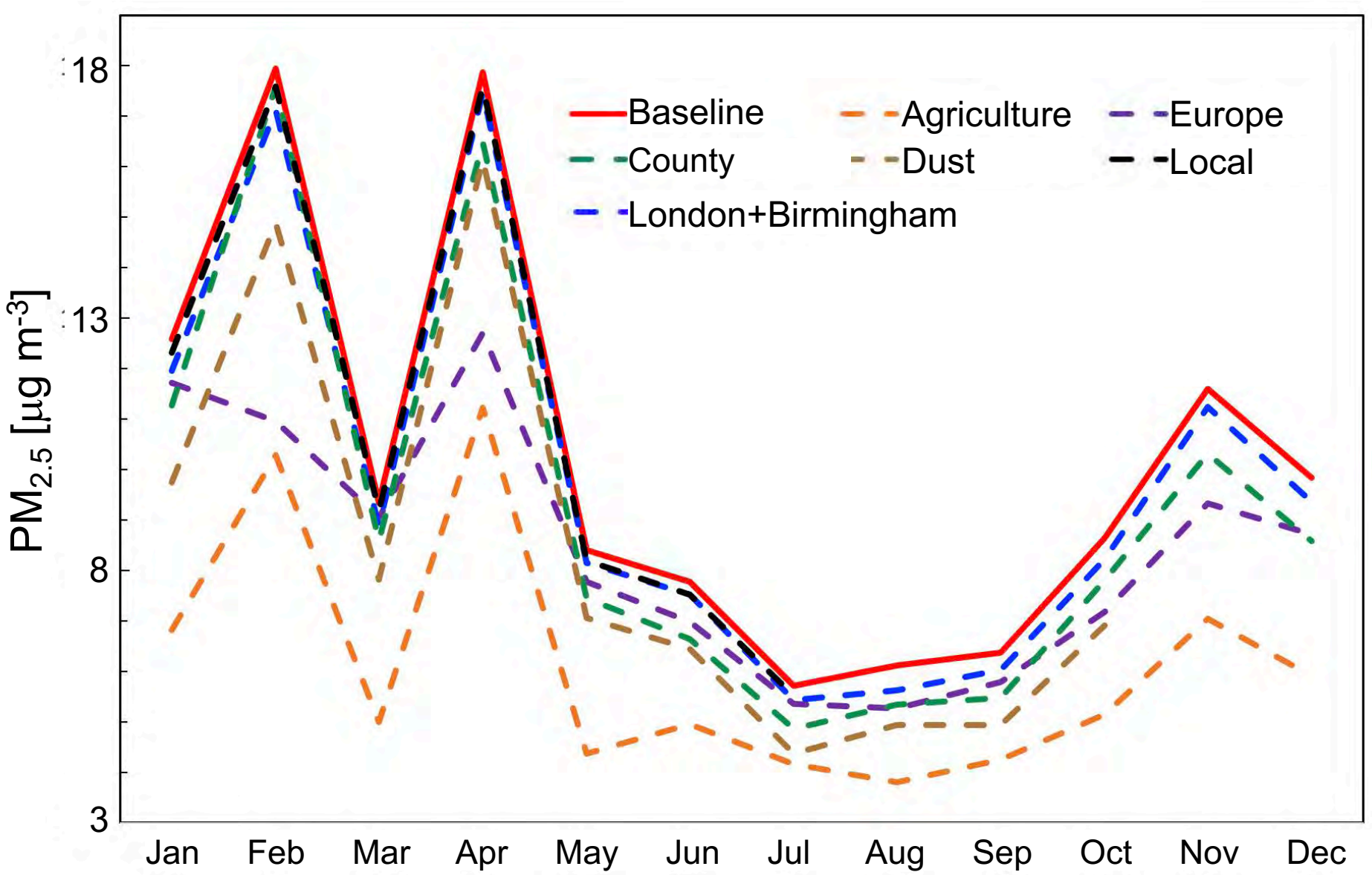
New product of NO_2 in the upper troposphere [pptv]



We share these data products with other scientists so that the community can use these to address uncertainties in our understanding of the upper troposphere

[Marais et al., 2020, doi:10.5194/amt-2020-399]

Local Air Quality in a City in the UK



The UK might adopt a stricter $PM_{2.5}$ standard of 10 $\mu g\ m^{-3}$ (the WHO guideline)

Fine particles ($PM_{2.5}$) hazardous to health are dominated by sources outside this city

This is a challenge for the council to address.

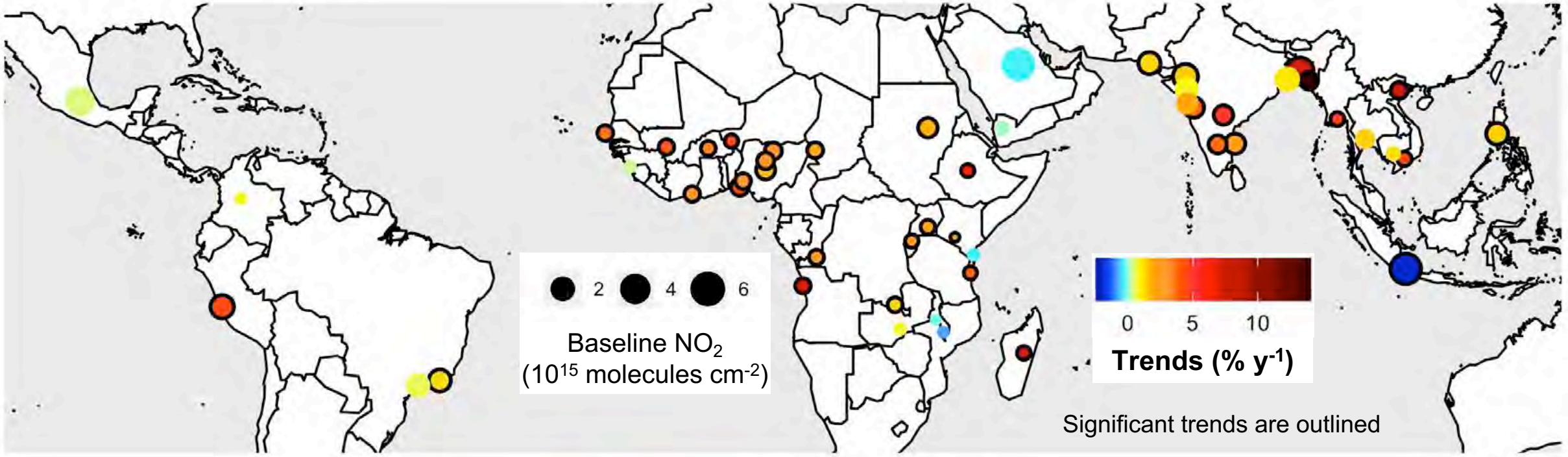
How do they deal with sources out of their control?

$PM_{2.5}$ in this city is mostly from agriculture and anthropogenic dust (year-round) and Europe (winter)

Trends in Air Quality in Cities of the Future

We examine trends in air quality in cities that are predicted to be amongst the largest cities by 2050

Trends in the air pollutant NO_2 from 2005 to 2018 obtained with satellite observations



We find large and significant trends in almost all cities

NO_2 is toxic at high concentrations and is also a precursor of surface ozone and $PM_{2.5}$

End User Needs for Next-Generation Small Satellites

Most satellite instruments are very expensive to build and launch

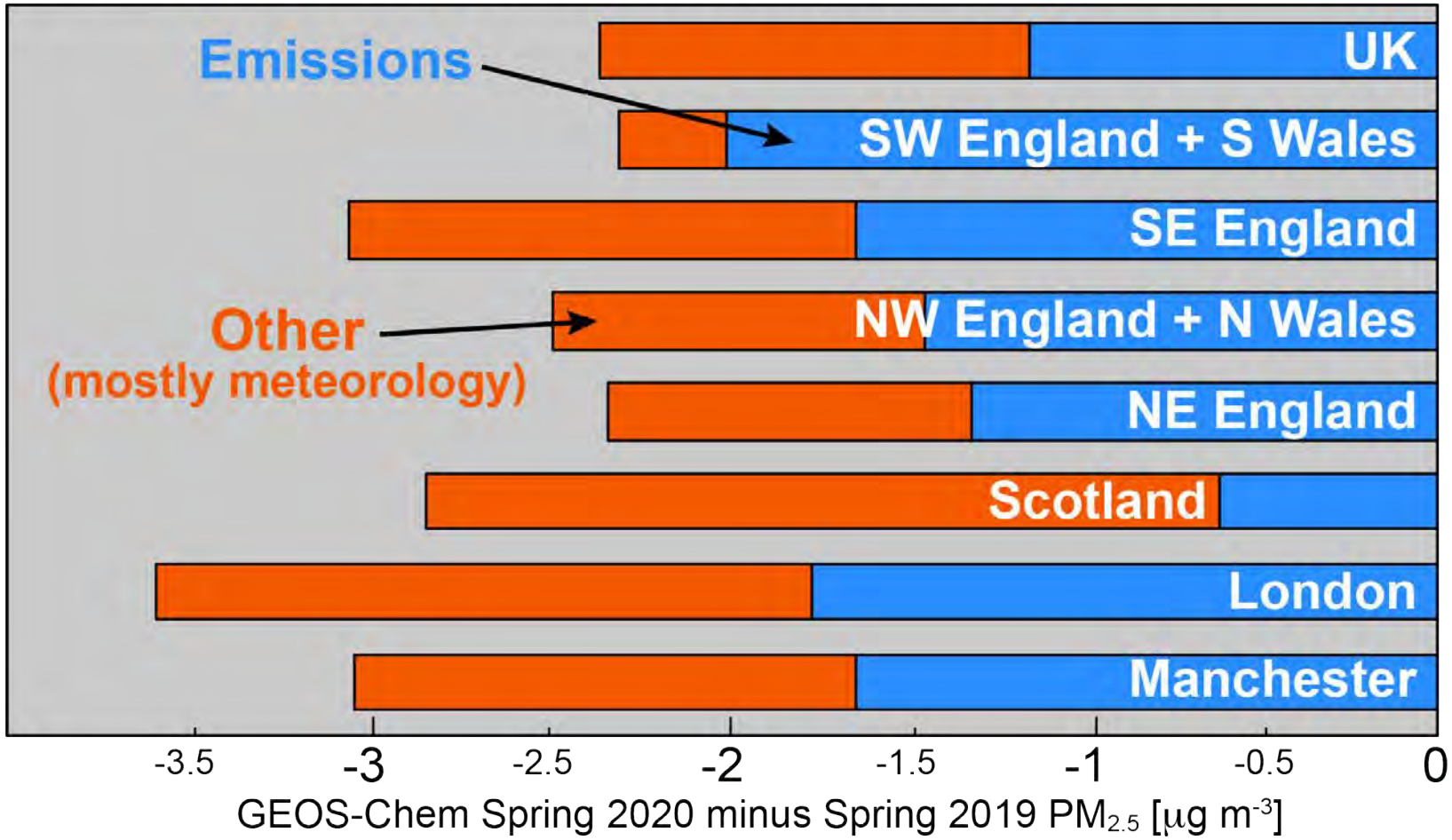
What environmental science questions can be answered with low-cost small satellite?

Project funded by the European Space Agency in collaboration with a small satellite manufacturer

The COVID-19 Lockdown and UK Air Quality

Widespread reports of improved air quality due to lockdowns to reduce transmission of SARS-CoV-2

Causes for decline in UK $PM_{2.5}$ during the Spring 2020 lockdown



Equal contributions from meteorology and reduced anthropogenic activity to improved air quality

Summary

- Air pollution comes from gases and aerosols released into the atmosphere
- Air pollution has adverse effects on our health, the built and natural environment, and food security, and alters the energy balance of the Earth (climate)
- Ongoing research is needed to estimate air quality in regions without measurements and to address uncertainties in our understanding of the sources and processes that contribute to degradation in air quality
- The air pollution research group at UCL uses a diverse range of research tools
- As a result, project topics range from local to regional to global air pollution
- We work with policymakers, local and national government, other research agencies, and the commercial sector to address urgent societal issues
- Skills gained from conducting this research are sought after in many sectors