Using Satellites to Monitor Air Quality in Cities

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TRACE

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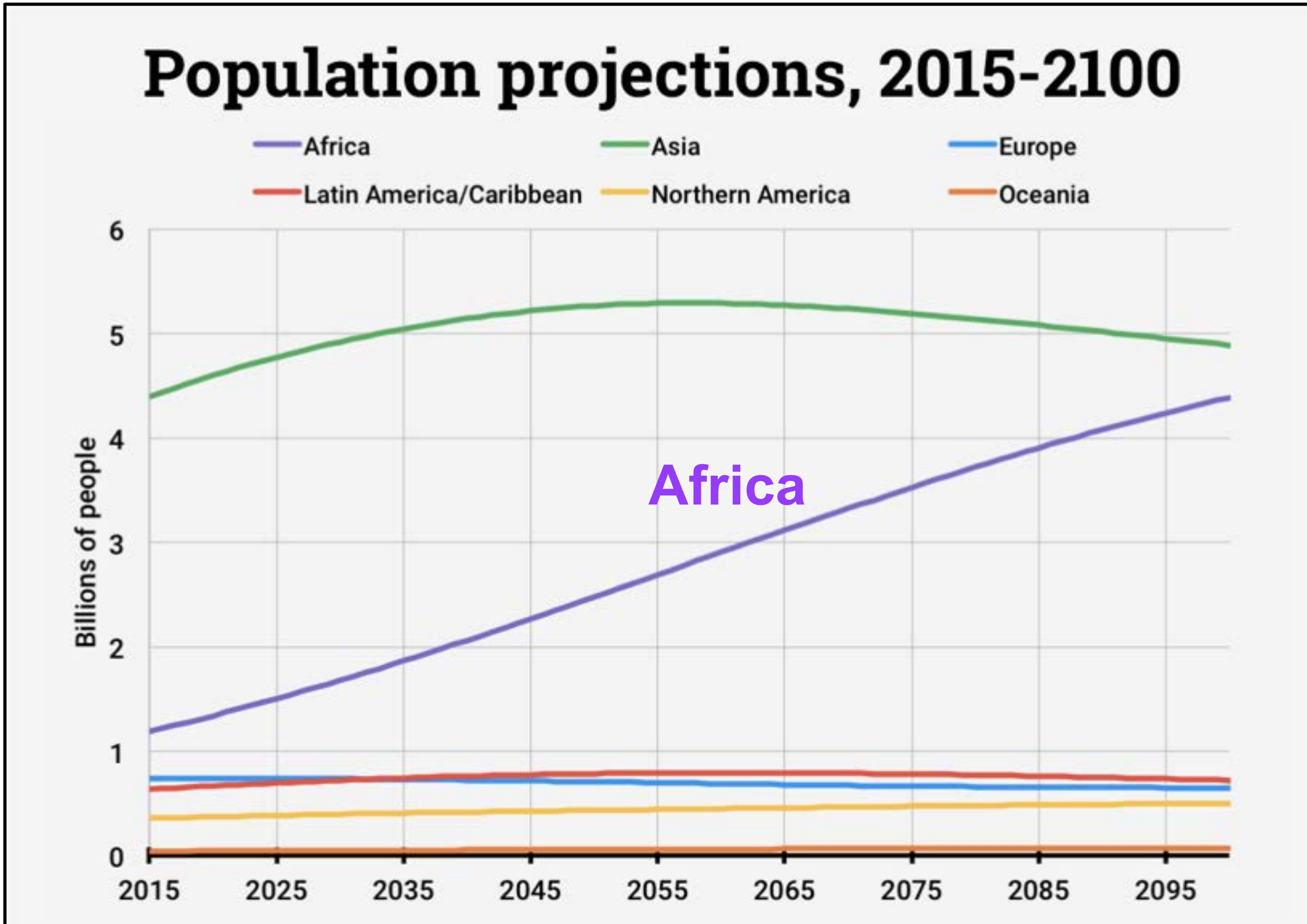
Part One

Building Capacity to Assess the Impact of Air Quality on Health in Africa

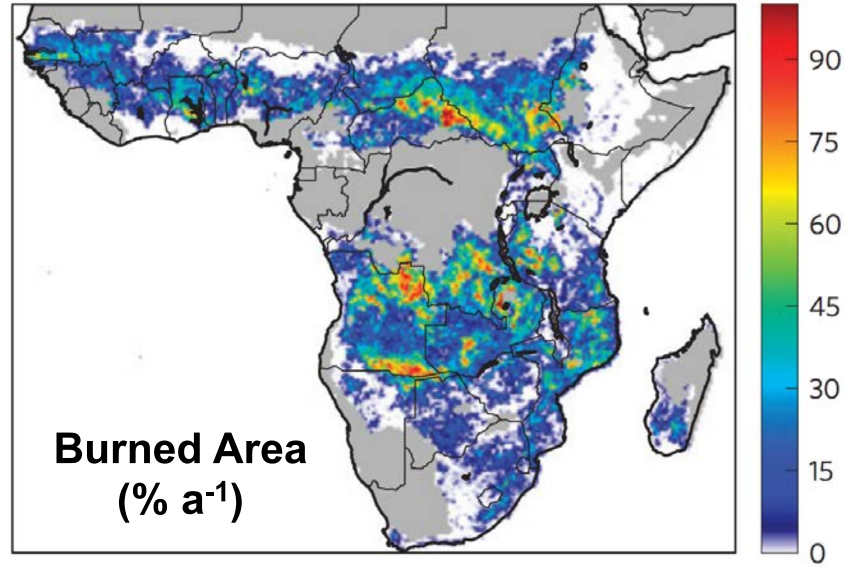
Africa's Population is Growing Rapidly

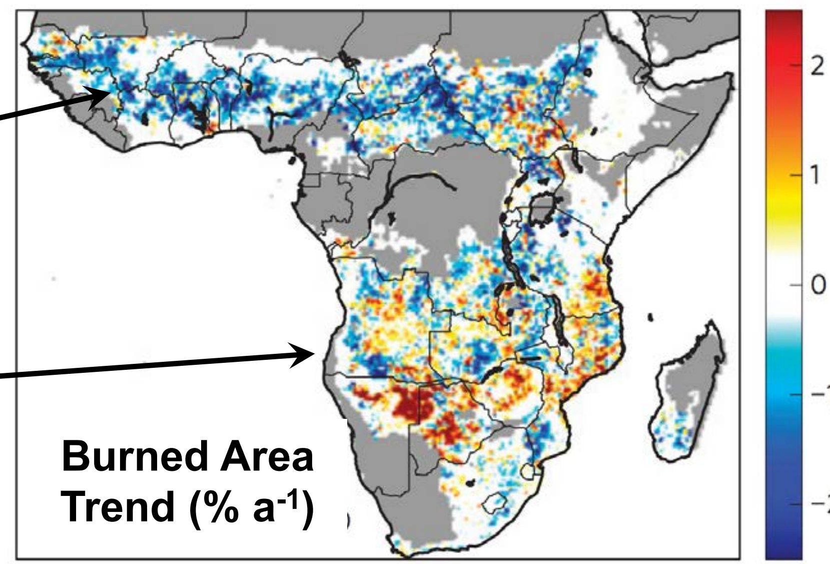


[UN, 2015]

Sources of Inefficient Combustion in Africa

Open Fires





Trends driven by cropland expansion

Variability attributed to decadal oscillations

[Andela and van der Werf, 2014]

Sources of Inefficient Combustion in Africa

Anthropogenic Activity





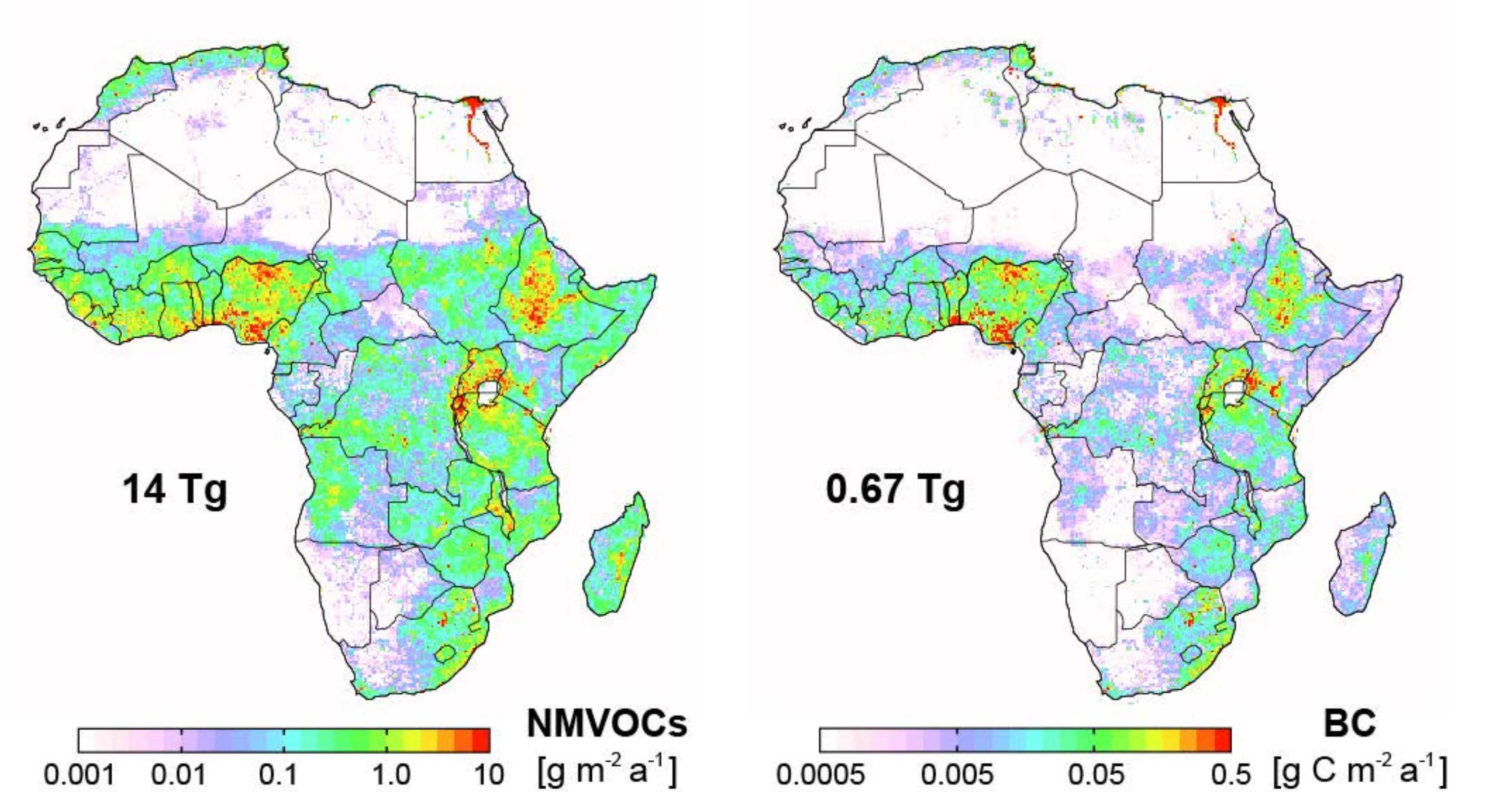




Building Capacity to Model Anthropogenic Emissions in Africa

DICE-Africa

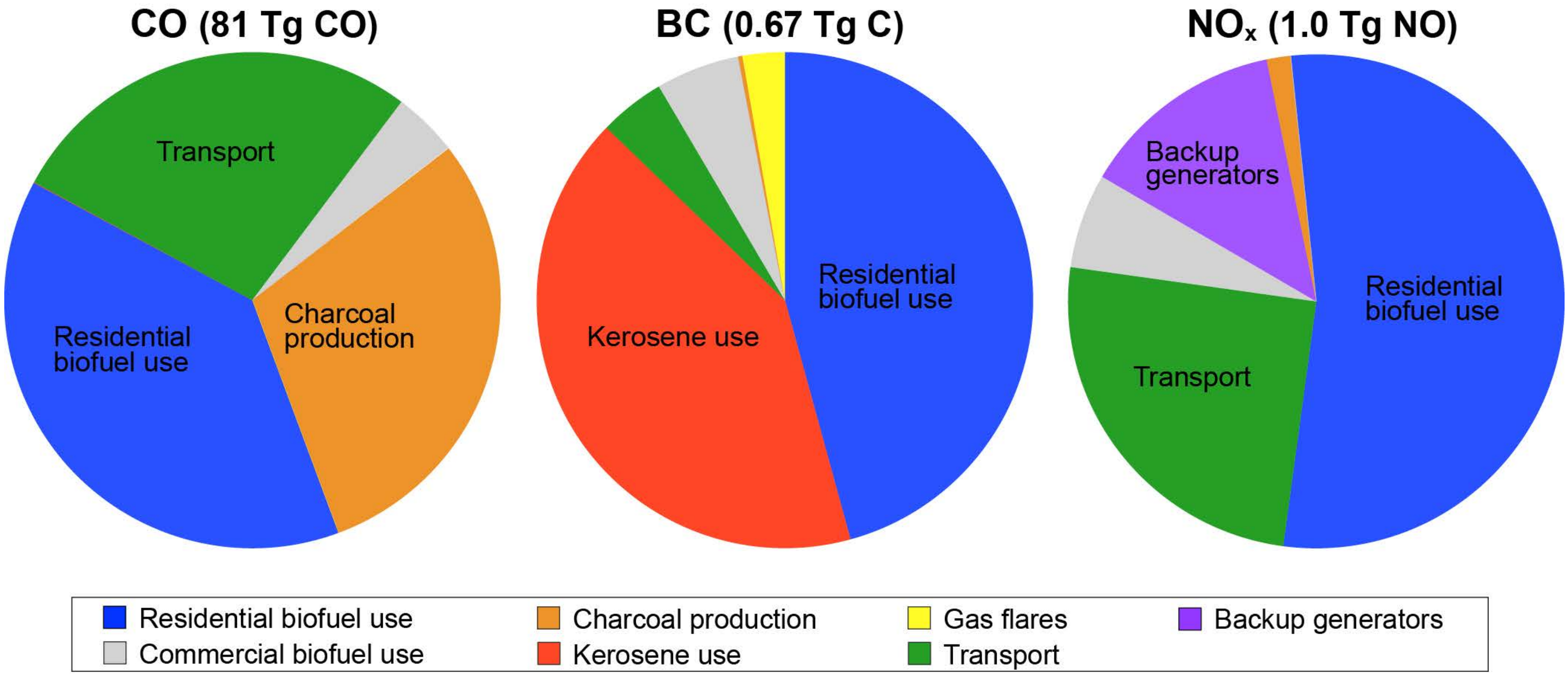
(Diffuse and Inefficient Combustion Emissions in Africa)



[Marais and Wiedinmyer, 2016]

Building Capacity to Model Anthropogenic Emissions in Africa

Sector Emissions from DICE-Africa

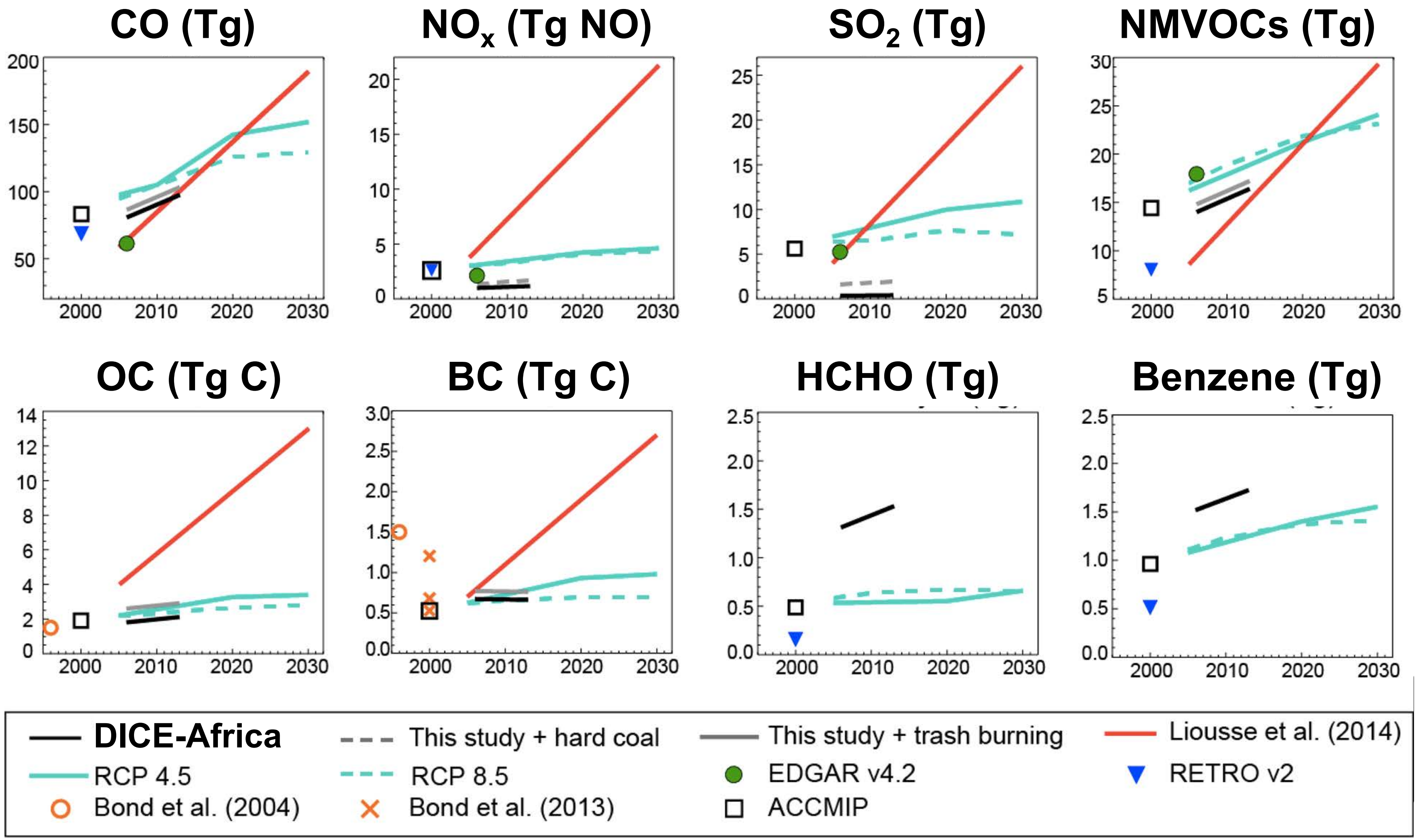


Residential biofuel use dominates all chemical species emissions

BC and CO emissions similar in magnitude to open fire emissions

NO_x emissions very low (high ozone production efficiencies)

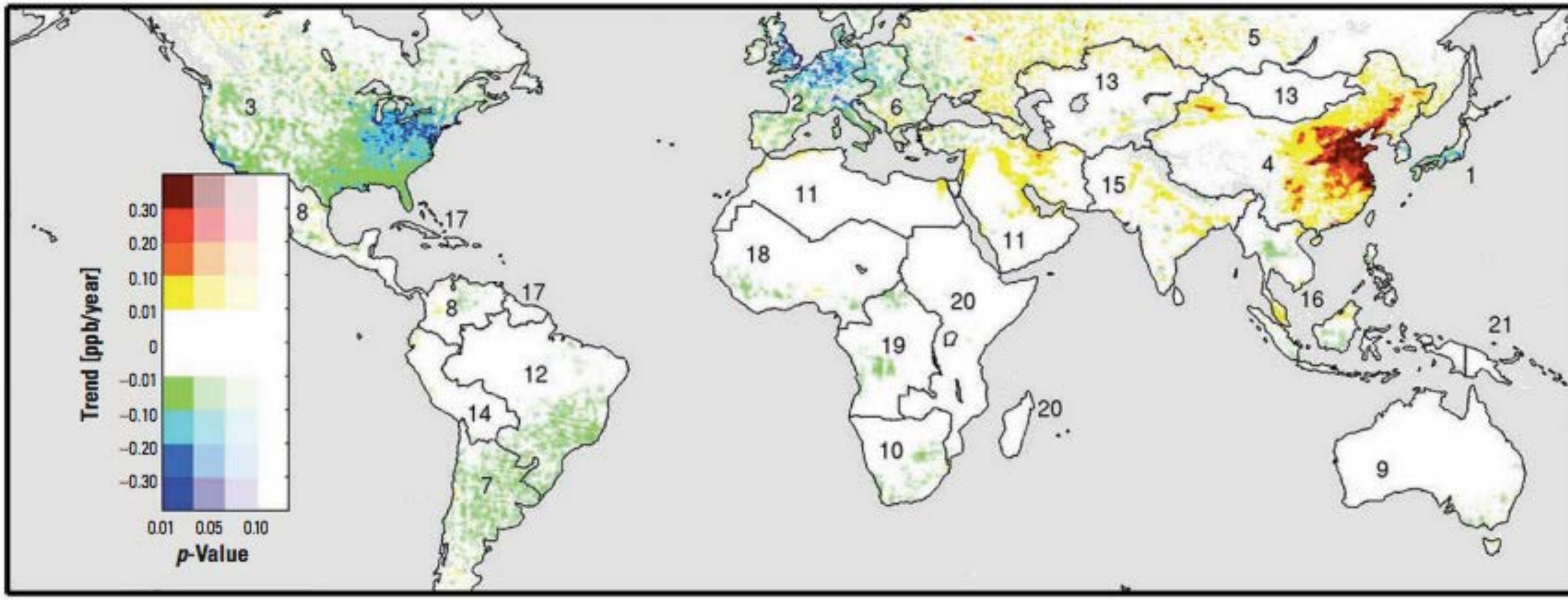
Emissions Trends and Projections for Africa



Wide range of emissions trends and projections. Which is correct?

No trend in satellite record

Trends in surface NO_2 inferred with satellite NO_2



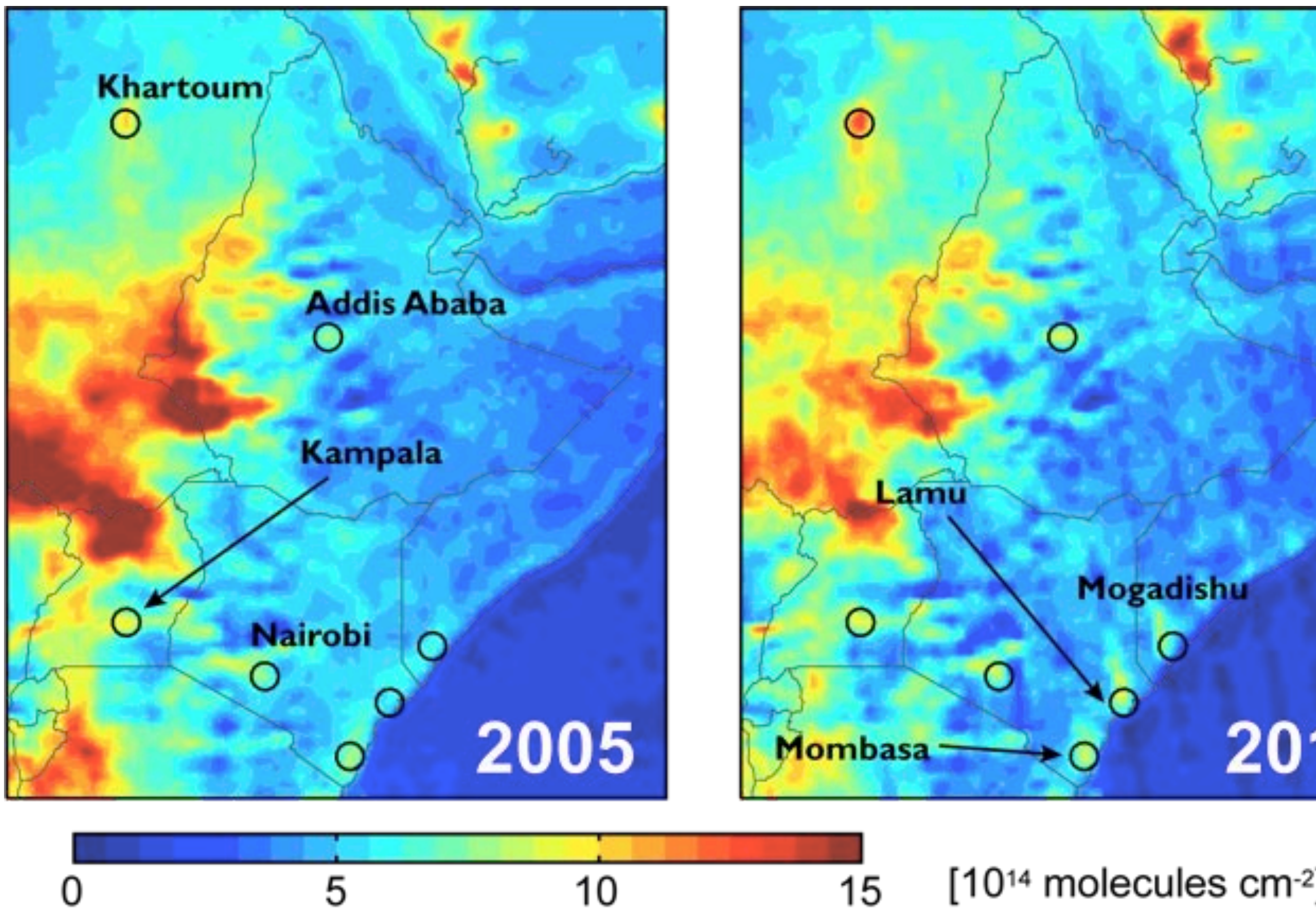
[Geddes et al., 2016]

Surface NO_2 inferred with GOME, SCIAMACHY, and GOME-2

Trend in Africa muted and opposite to what's projected

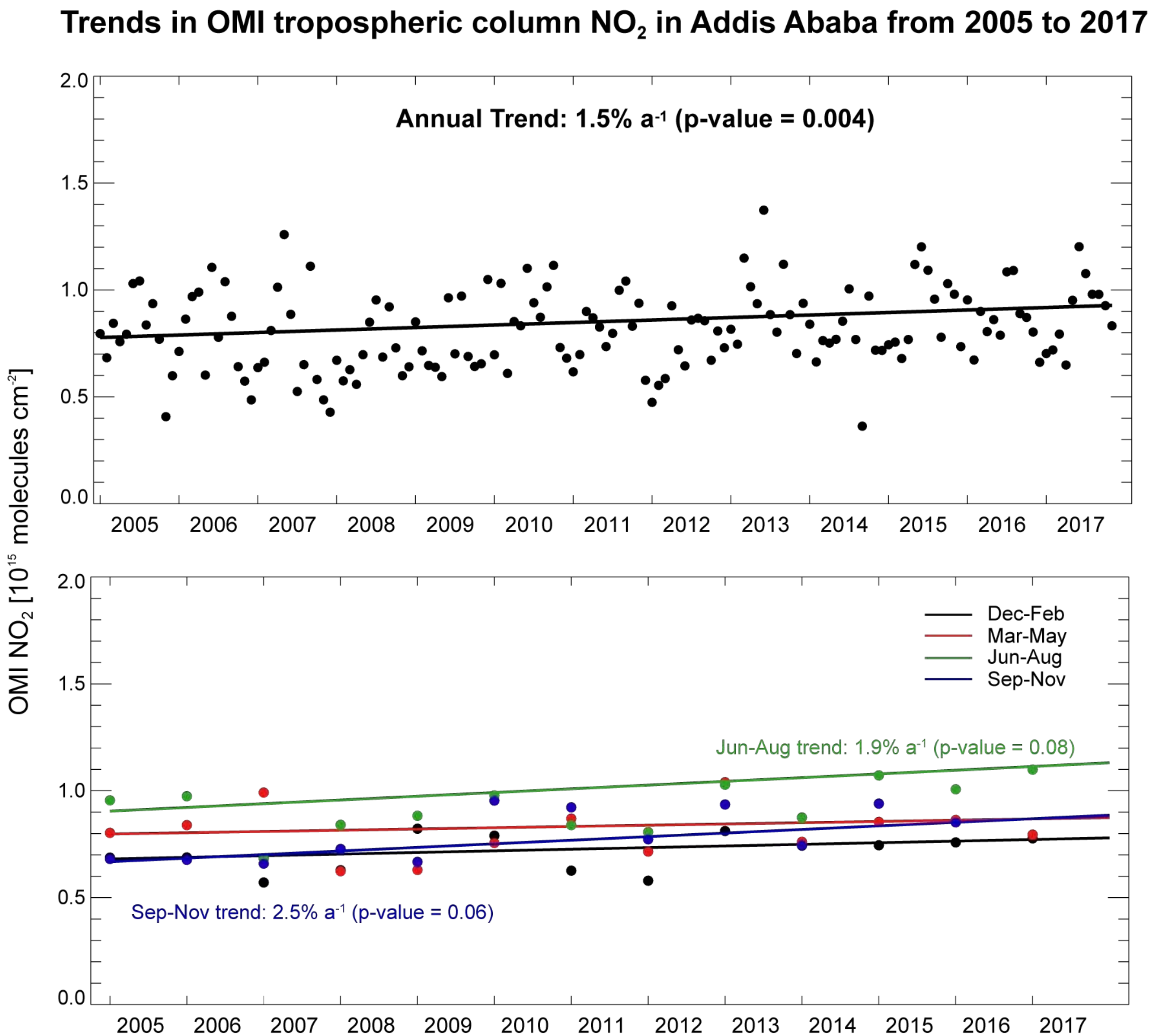
Some evidence of increases in NO_2

East Africa annual mean OMI NO_2



Increase in OMI NO_2 in cities and at ports, but column concentrations are low.

Trend Estimate for Addis Ababa



NO_2 concentrations in UK cities are at least double that in Addis Ababa

Inventory of air pollution from charcoal production, use, transport

Production increasing at 6-9% per year

Most charcoal used in-country.
Some exported (South Africa, Namibia, Somalia).

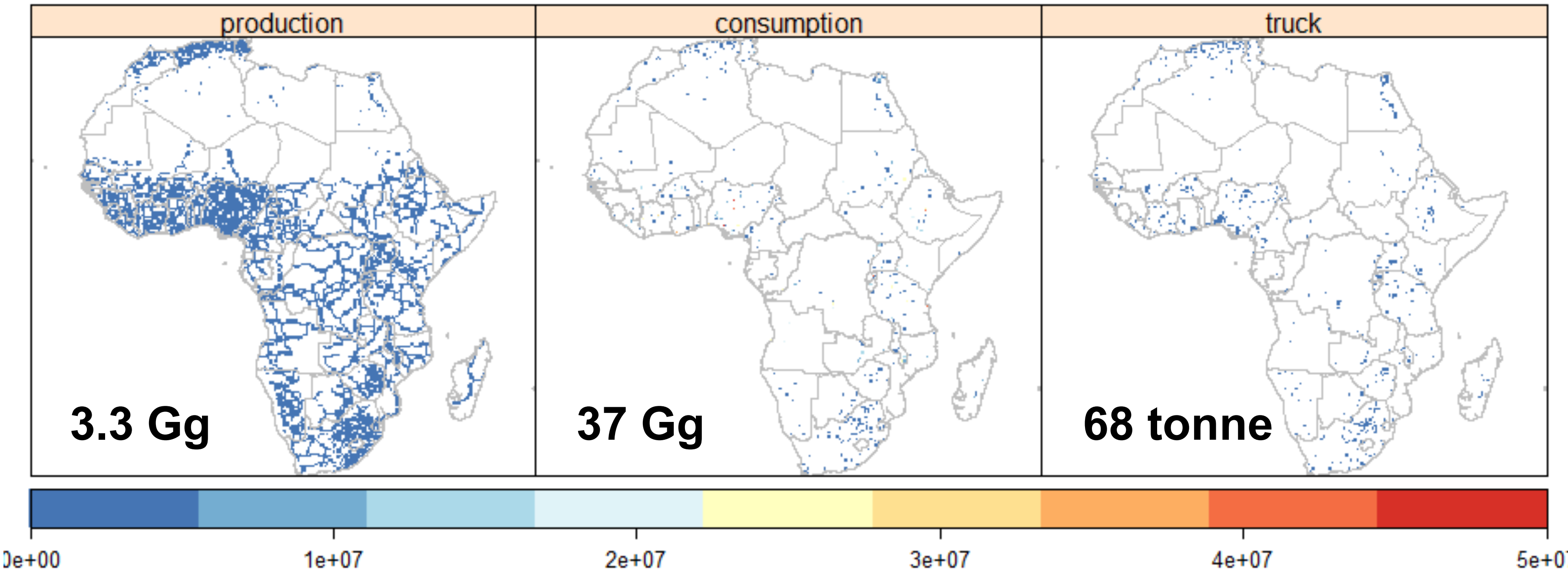
Production

Transport

Use

Spatial Distribution of Pollutants

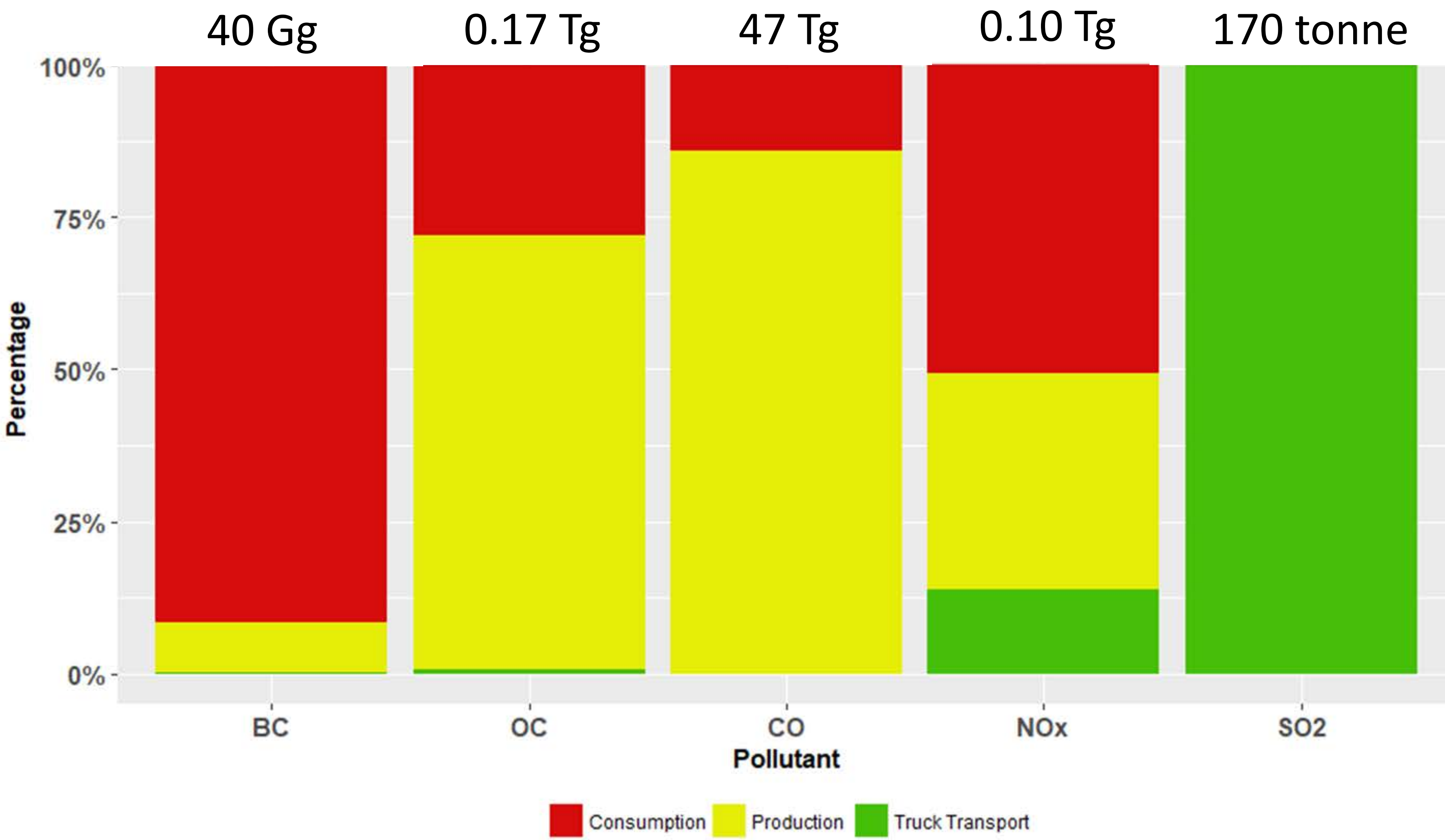
Black carbon (BC) Emissions in grams per gridsquare



Emissions are on a 0.1^0 x 0.1^0 grid

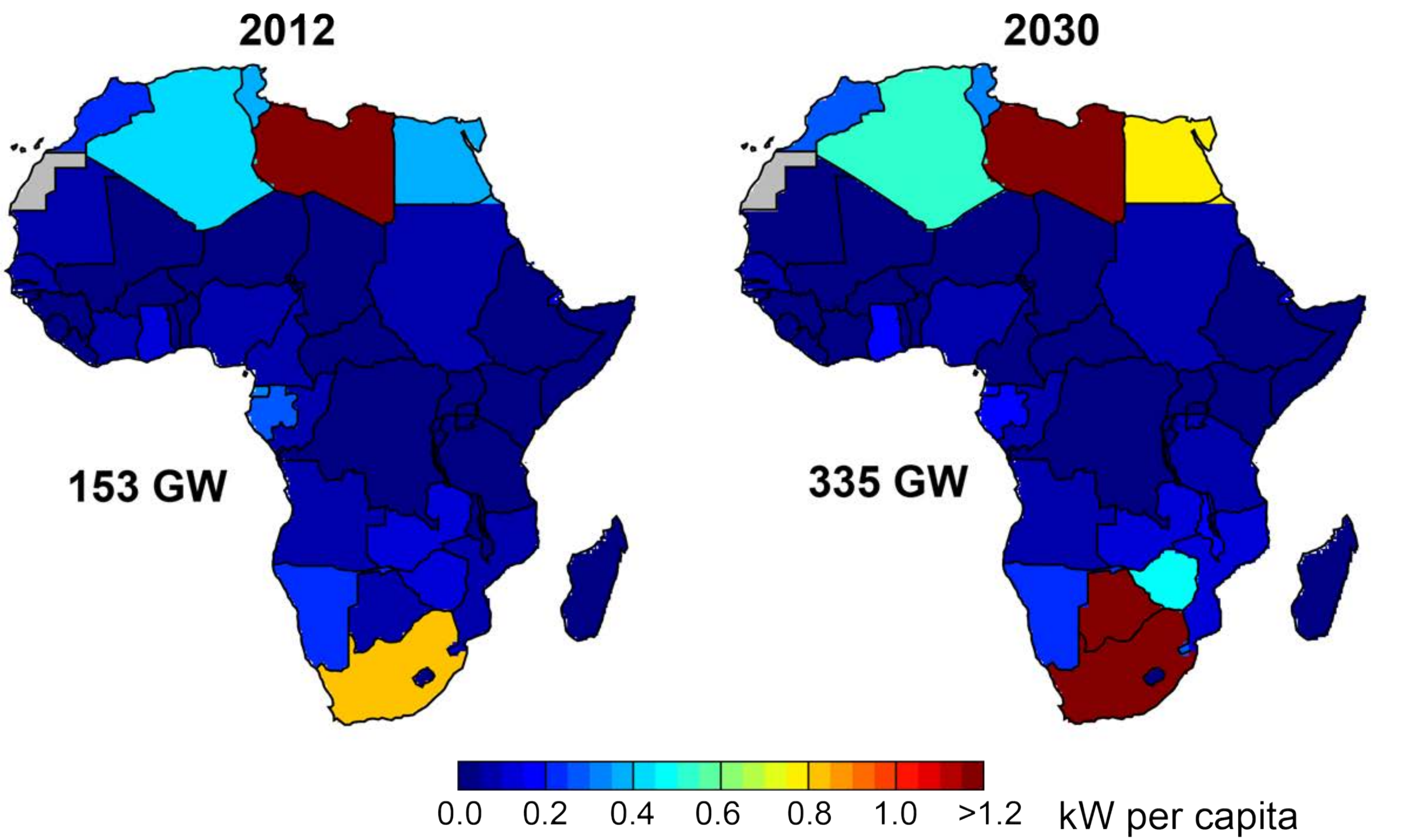
Emissions mapping by **Alfred Bockarie**, PhD student at UoB

Contribution of activities to pollutant emissions



Future Fossil Fuel Impact on Health

Per capita generating capacity

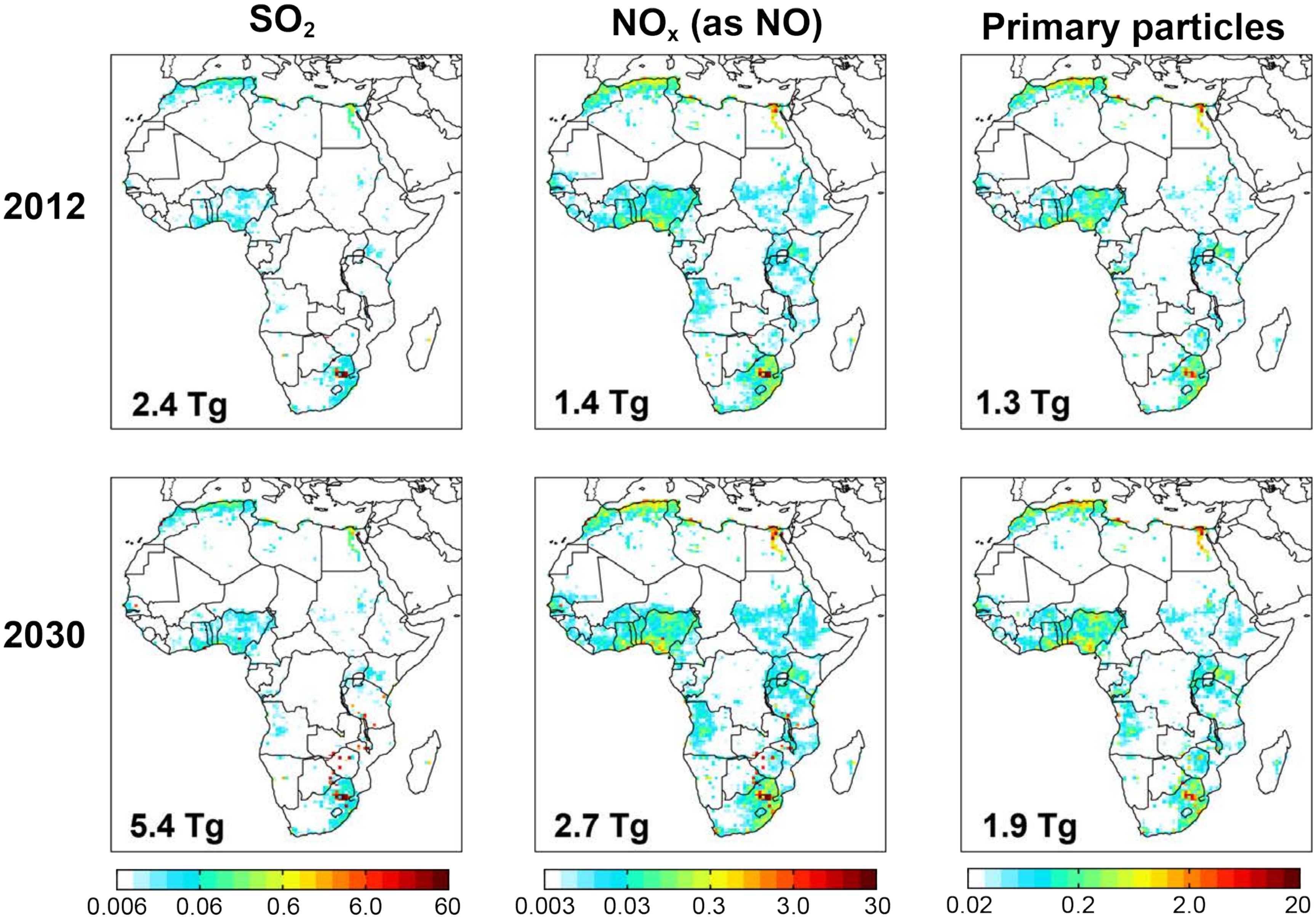


2012-2030 **installed capacity** increase: 120%

2012-2030 **population** increase: 54%.

The Wallace Foundation®

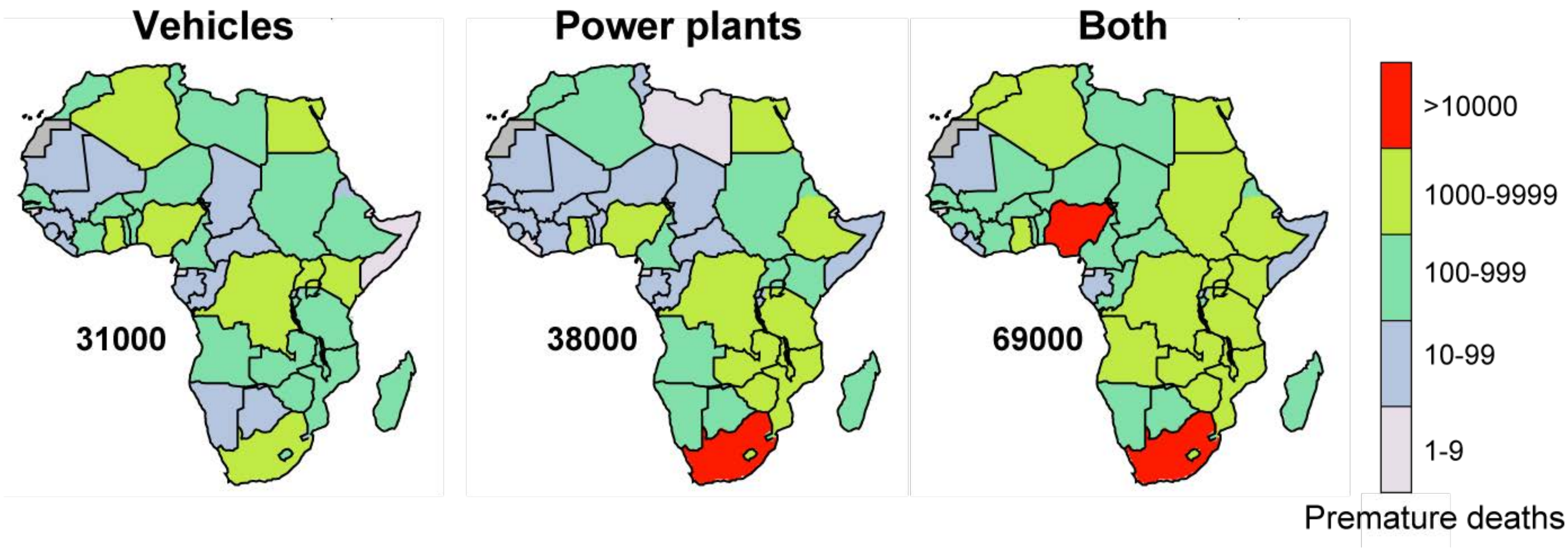
Air Pollution Emissions (g m^{-2} a^{-1})



At resolution of model: **0.5º latitude × 0.006º longitude**

Health Burden for People > 14 years

Additional deaths in 2030 due to exposure to fine particles ($PM_{2.5}$)



Large proportion of health burden can be attributed to population increase

Health calculations by **Alina Vodonos**, Harvard

Part Two

Air Quality Monitoring with Satellite Observations

Debilitating Fines for Infringements

UK given days to show it will comply with EU air quality laws

UK and eight other states will need to take drastic measures on illegal air pollution to avoid court referrals next week, says EU

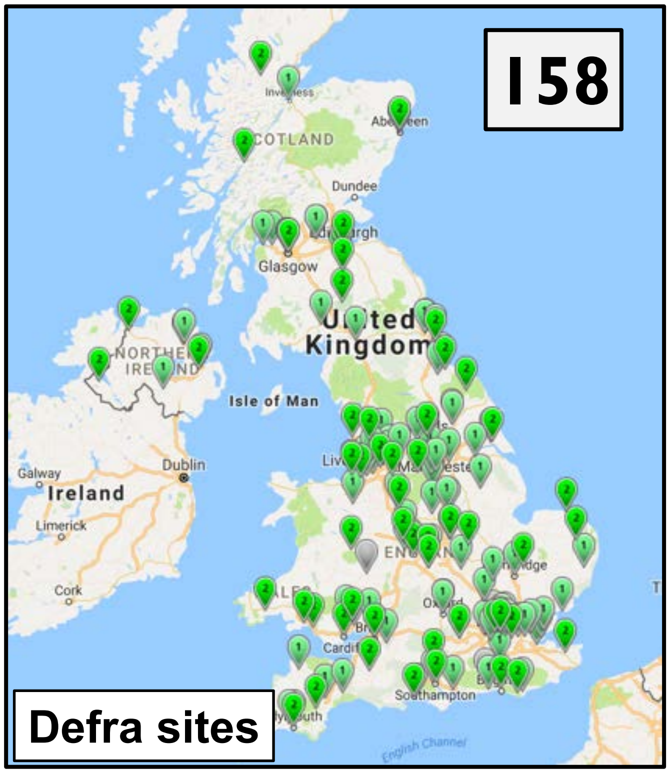
The Guardian

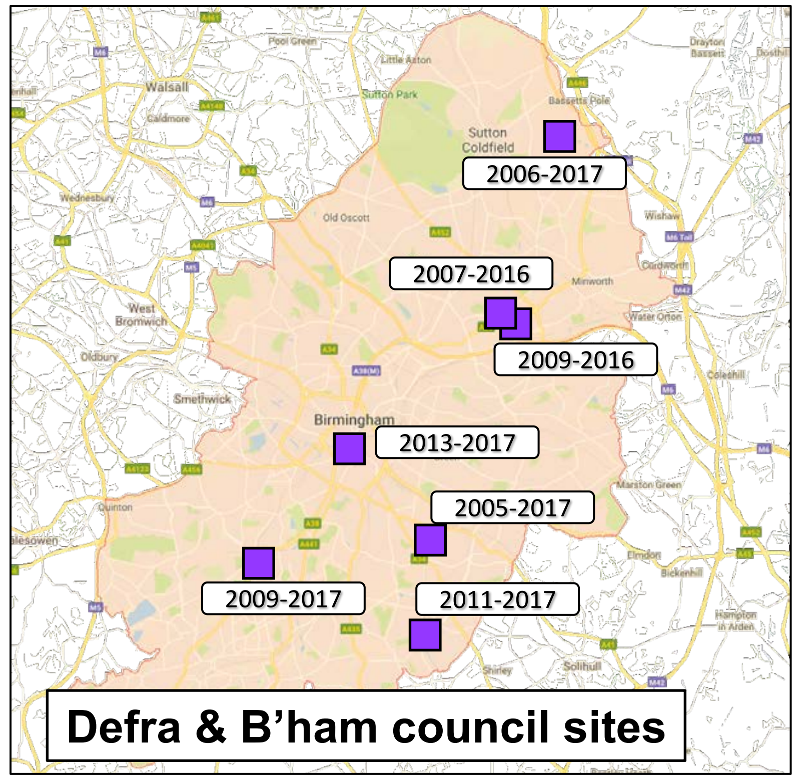
UK and city councils face fines of millions of GBP

Air Pollution and Green Space Monitoring in Cities

COSTLY to MONITOR

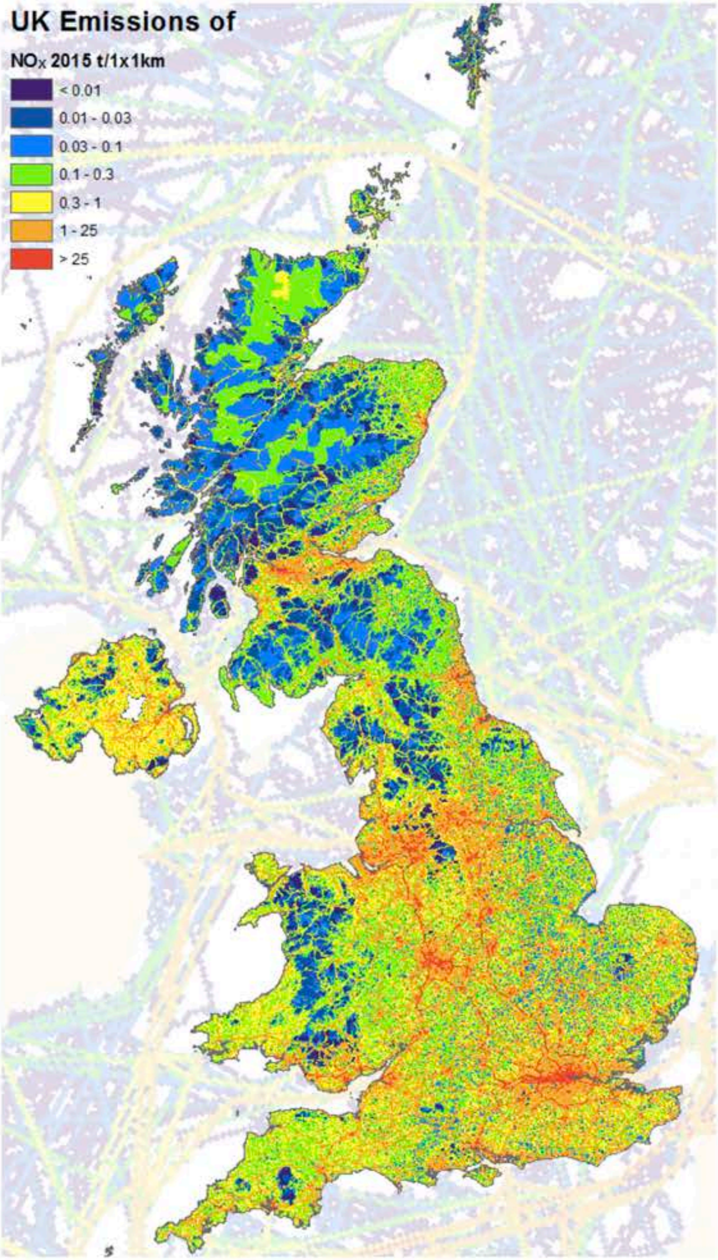
£52,000-£173,000 per monitor





LARGE GAPS

Long-term Changes in Emissions



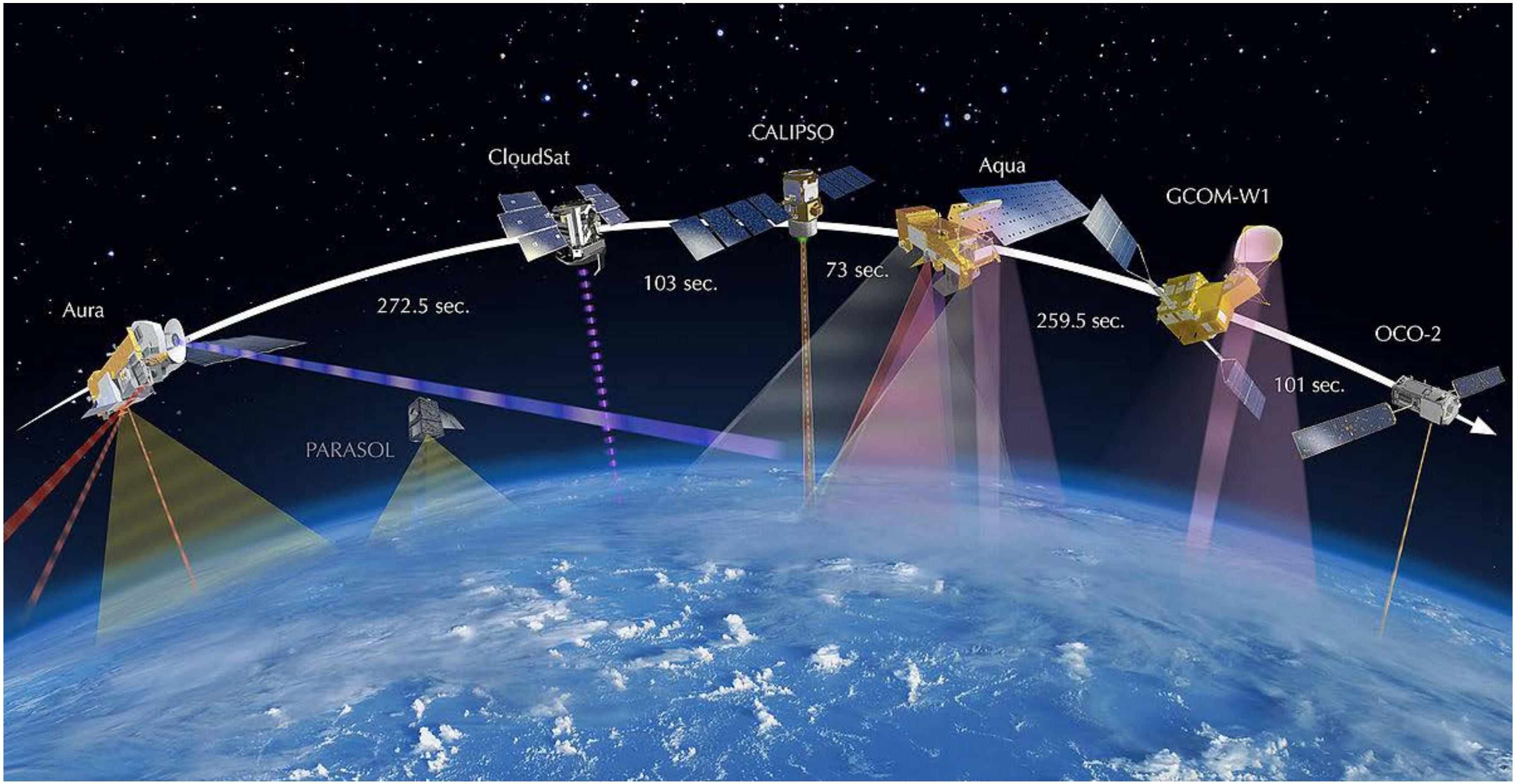
UK Emissions of NO_x in 2015

Missing information:
long-term changes in pollution sources

[naei.beis.gov.uk]

Satellite observations as the Solution

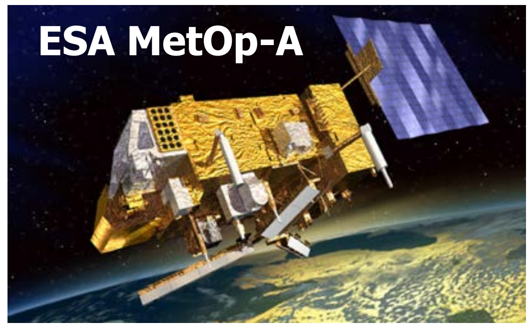
NASA Afternoon-Train (A-Train)



Long record of diverse observations

12+ years of air pollutants and vegetation dynamics from NASA and ESA satellites

HCHO NO_2 SO_2



NH_3

CO AOD LAI EVI

Air pollutants regulated by EU

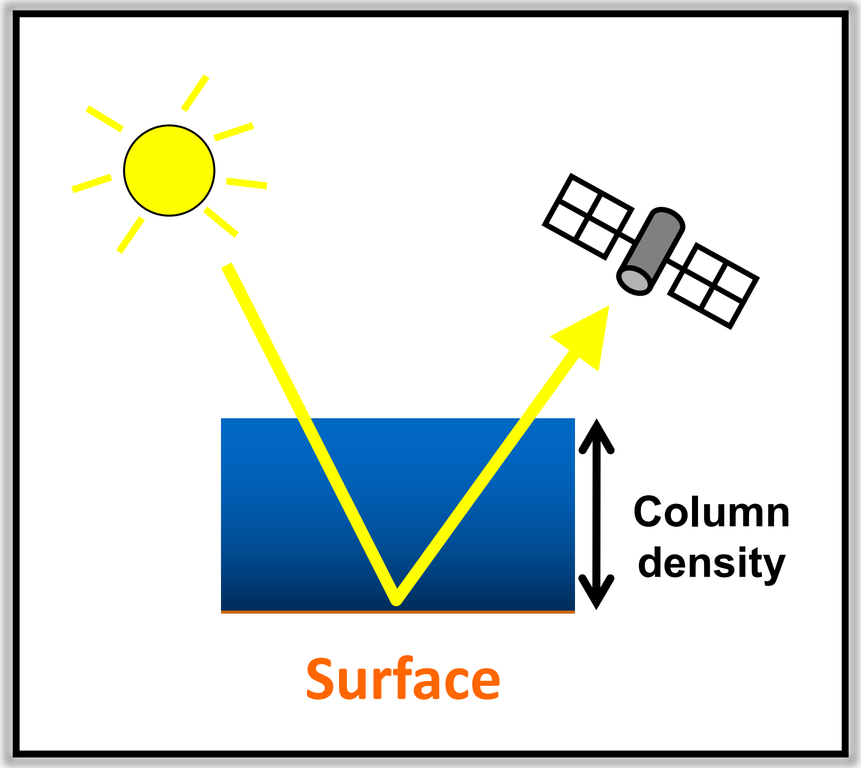
Constraints on regulated air pollutants

Vegetation extent/cover

Vegetation greenness

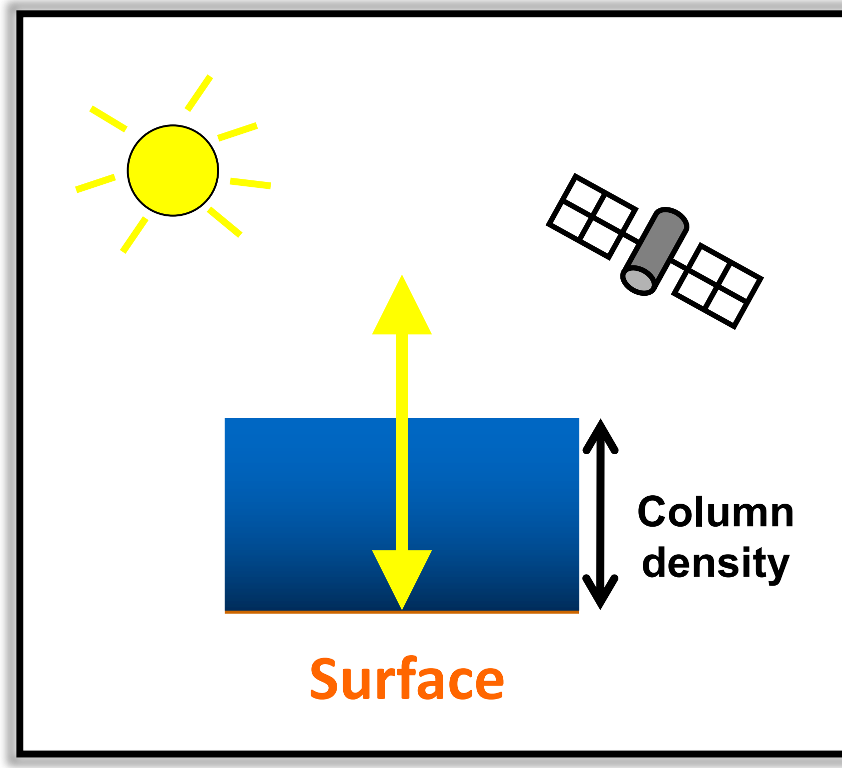
Retrieval of Satellite Observations

One: Spectral Fitting



Concentration along viewing path

Two: Air Mass Factor

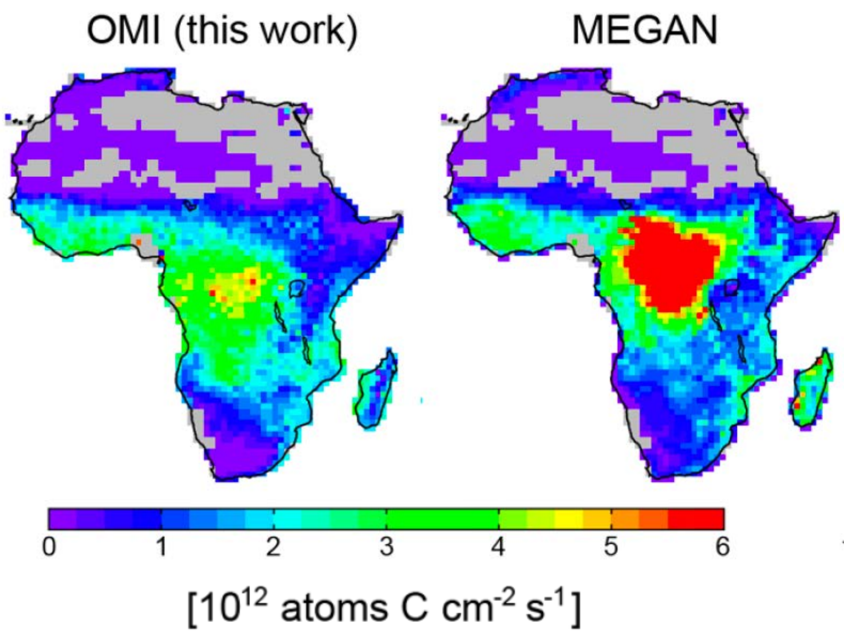


True vertical column

Challenge: Does variability in column represent variability at the surface?

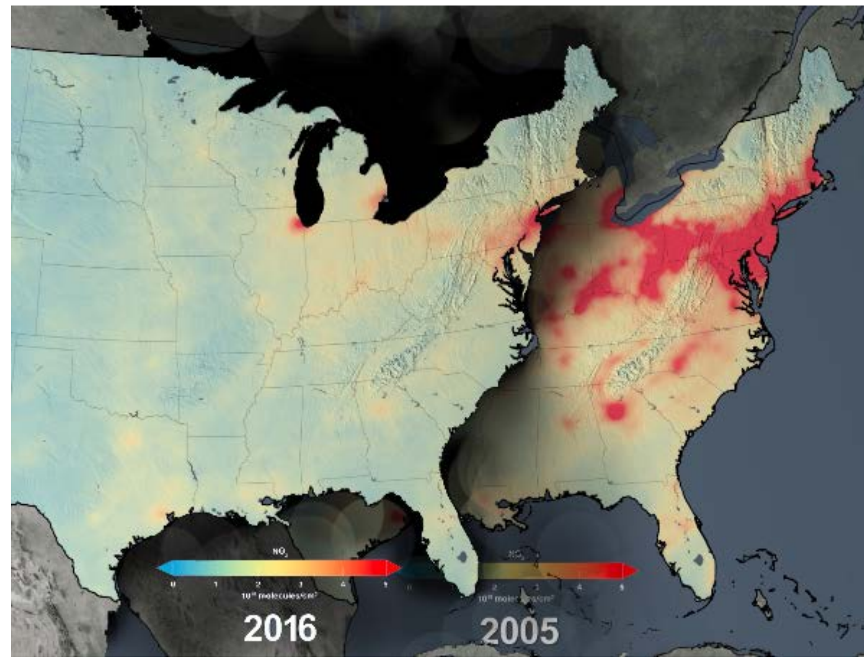
Examples of Constraints on Surface Sources

Biogenic Isoprene Emissions from space-based formaldehyde observations



[Marais et al., 2012; 2014]

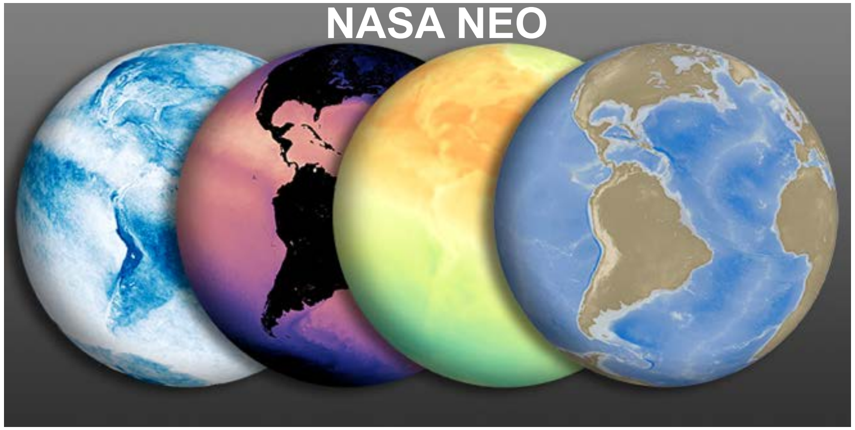
Decline in NO_2 over the Northeast US

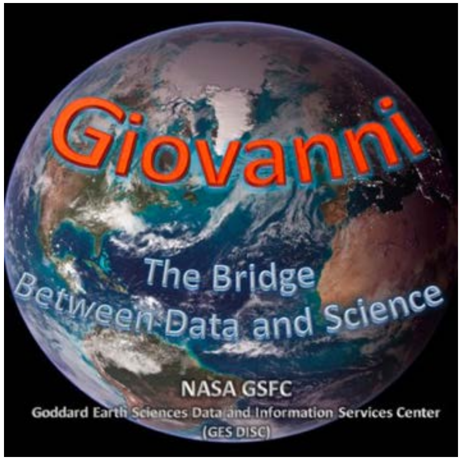


[https://aura.gsfc.nasa.gov/science/gallery-omi.html]

The link between policymakers and scientists is often tenuous.

Increasing Number of Online Tools





QA4ECV

Copernicus
Europe's eyes on Earth

Atmosphere Monitoring Service

openaq

Google Earth Engine

Tool for Recording and Assessing the City Environment

TRACE

Online database of air pollution concentrations and vegetation dynamics from EO to evaluate AQ and green space at the city level

Developed with Involvement of Multiple Sectors

NERC
SCIENCE OF THE ENVIRONMENT

EPSRC
Engineering and Physical Sciences Research Council

CATAPULT
Future Cities

CATAPULT
Satellite Applications

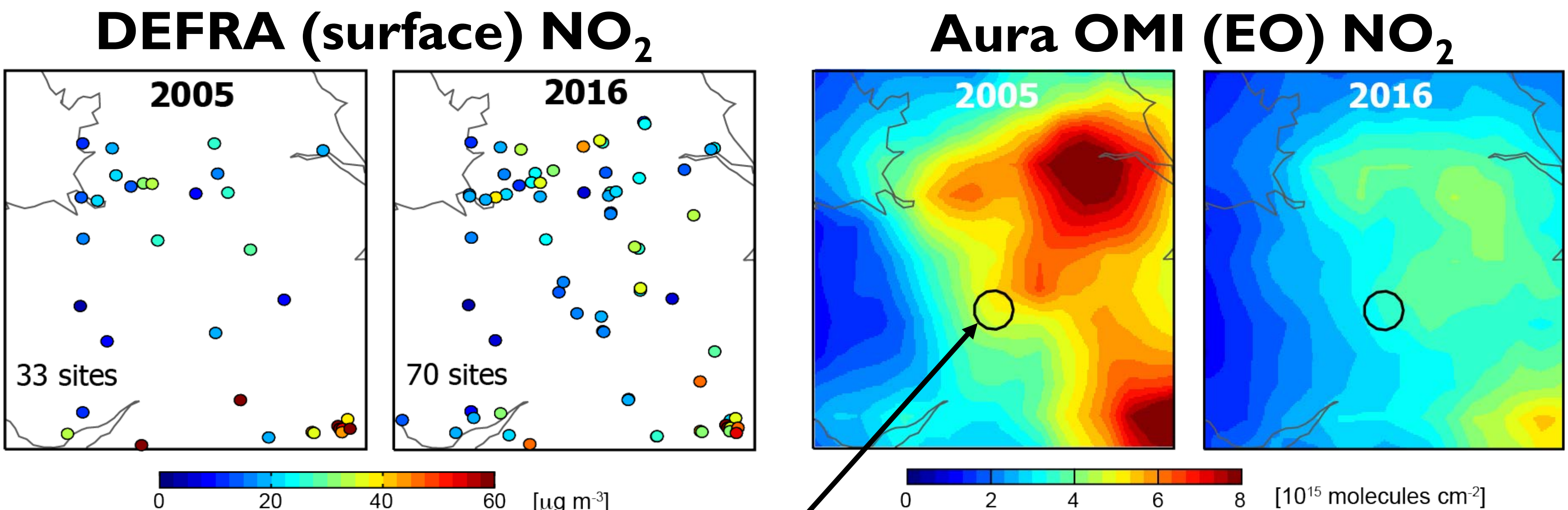
RICARDO

Birmingham City Council

defra
Department for Environment Food and Rural Affairs

Complete coverage achieved with EO

NO_2 is a precursor of ozone and fine particles

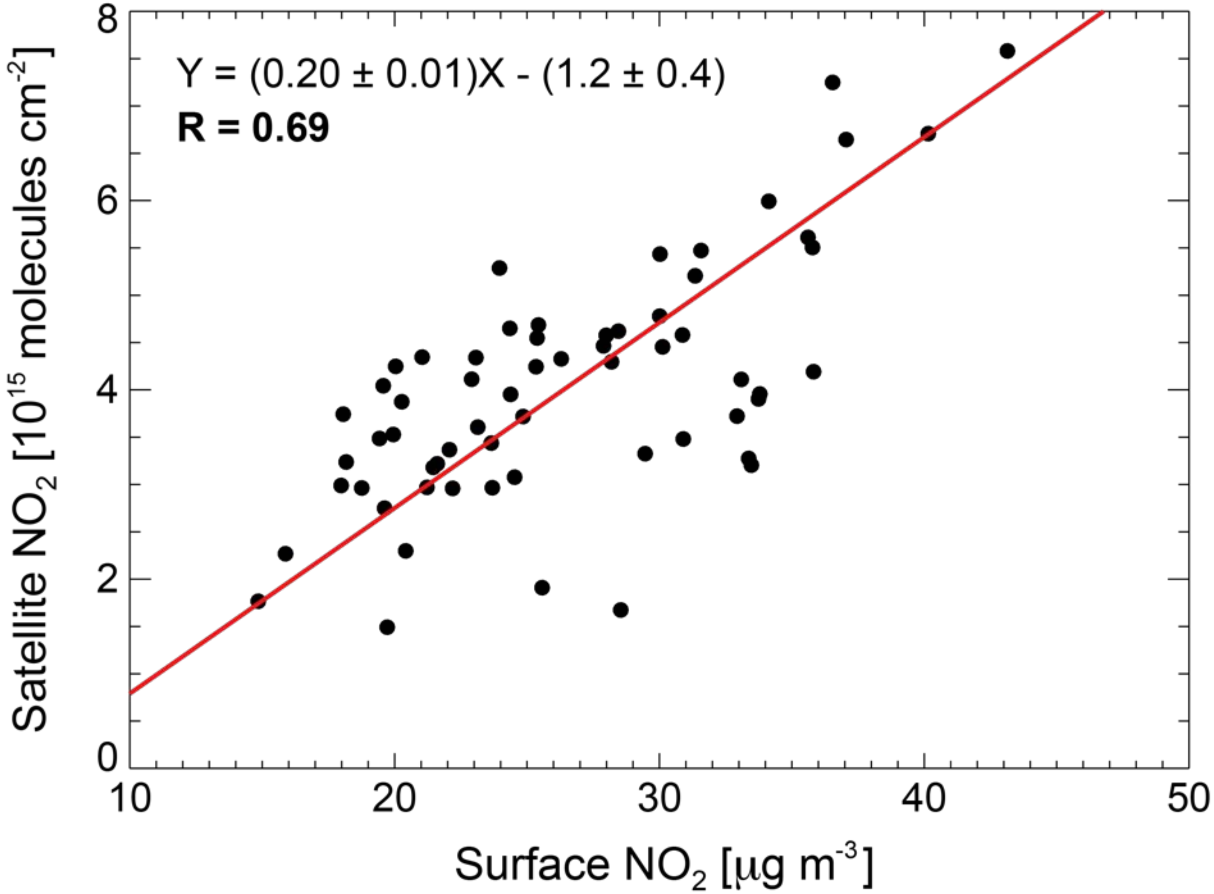


Birmingham: 3% per year decline in NO_2

Validate over Birmingham

UK NO_2 out of compliance with EU standards

Consistency between surface and satellite NO_2:



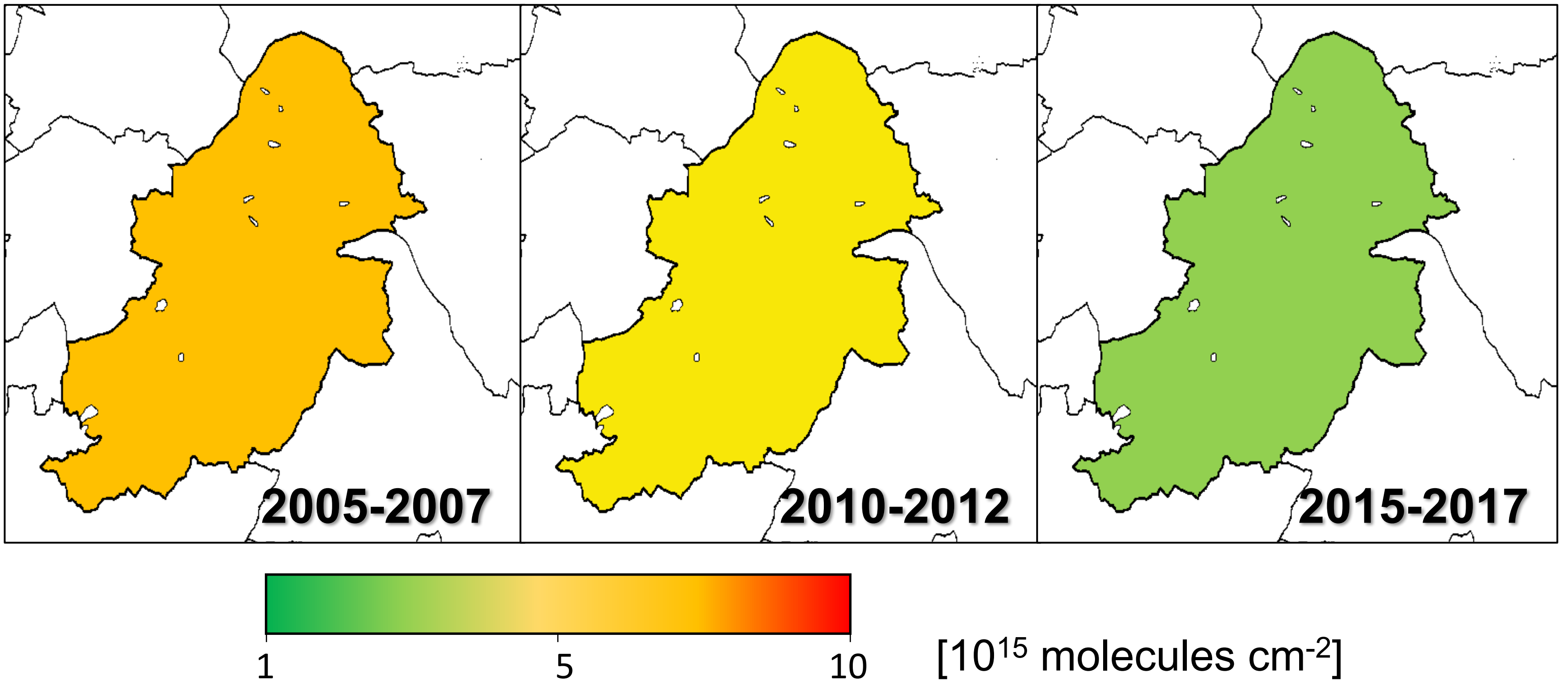
Data analysis by **Karn Vohra**, PhD student at UoB

Application to Birmingham

Decline in NO_2 over Birmingham

3.4% per year

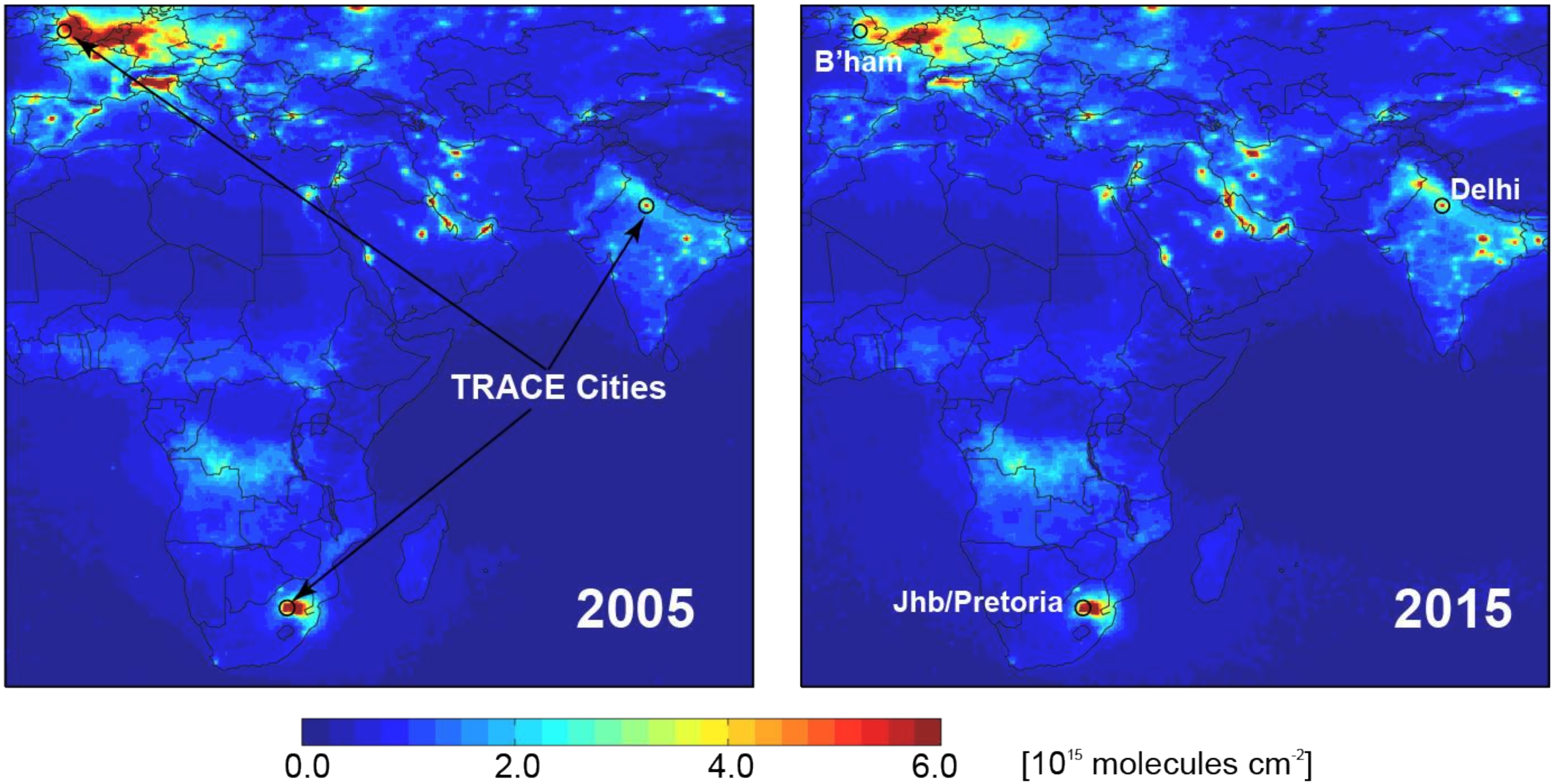
44% from 2005 to 2017



Apply to cities at different development stages

Initial target cities for TRACE

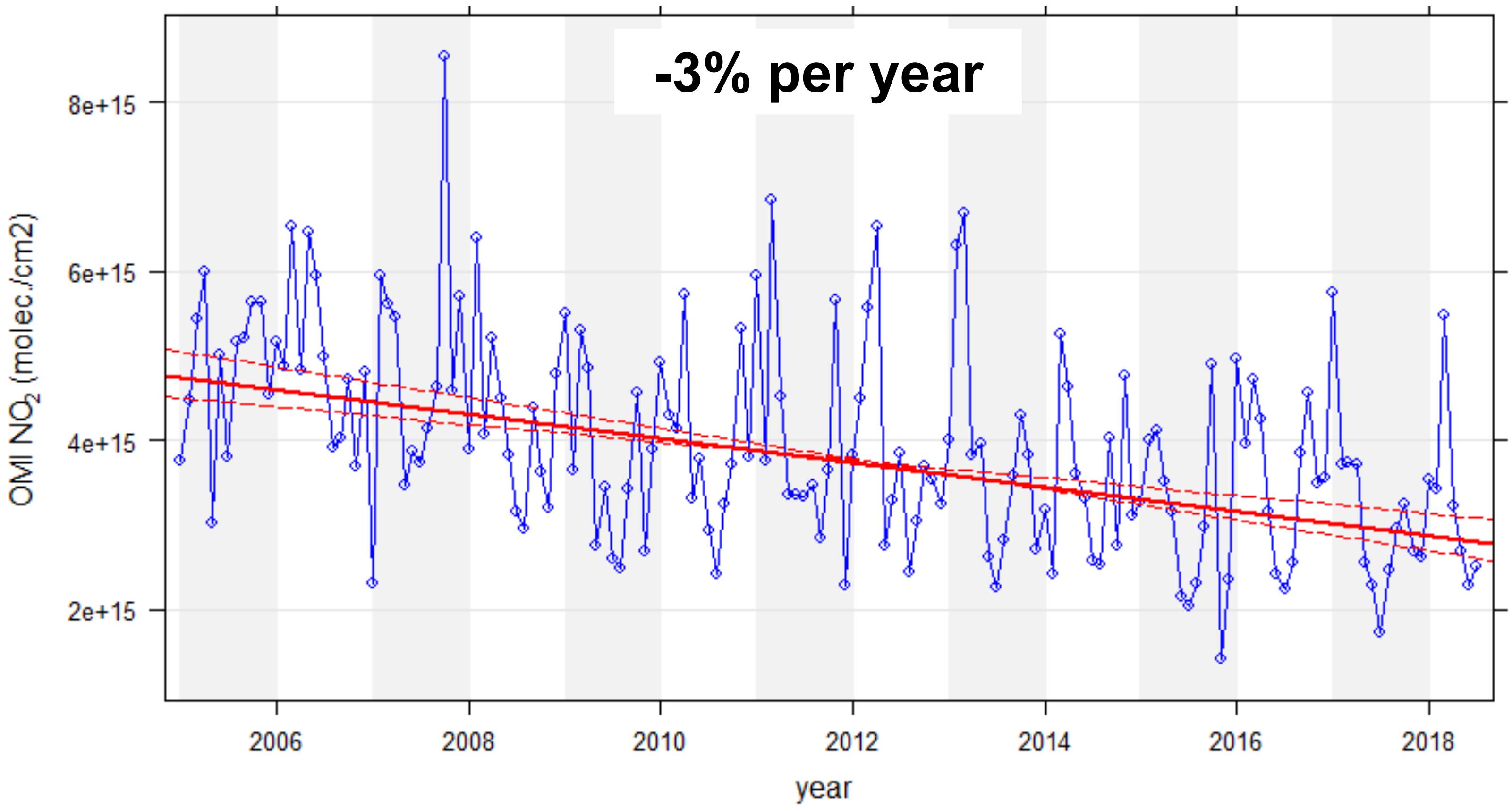
Maps of annual mean OMI NO_2



Now also includes: London, Kanpur and Bengaluru (India)

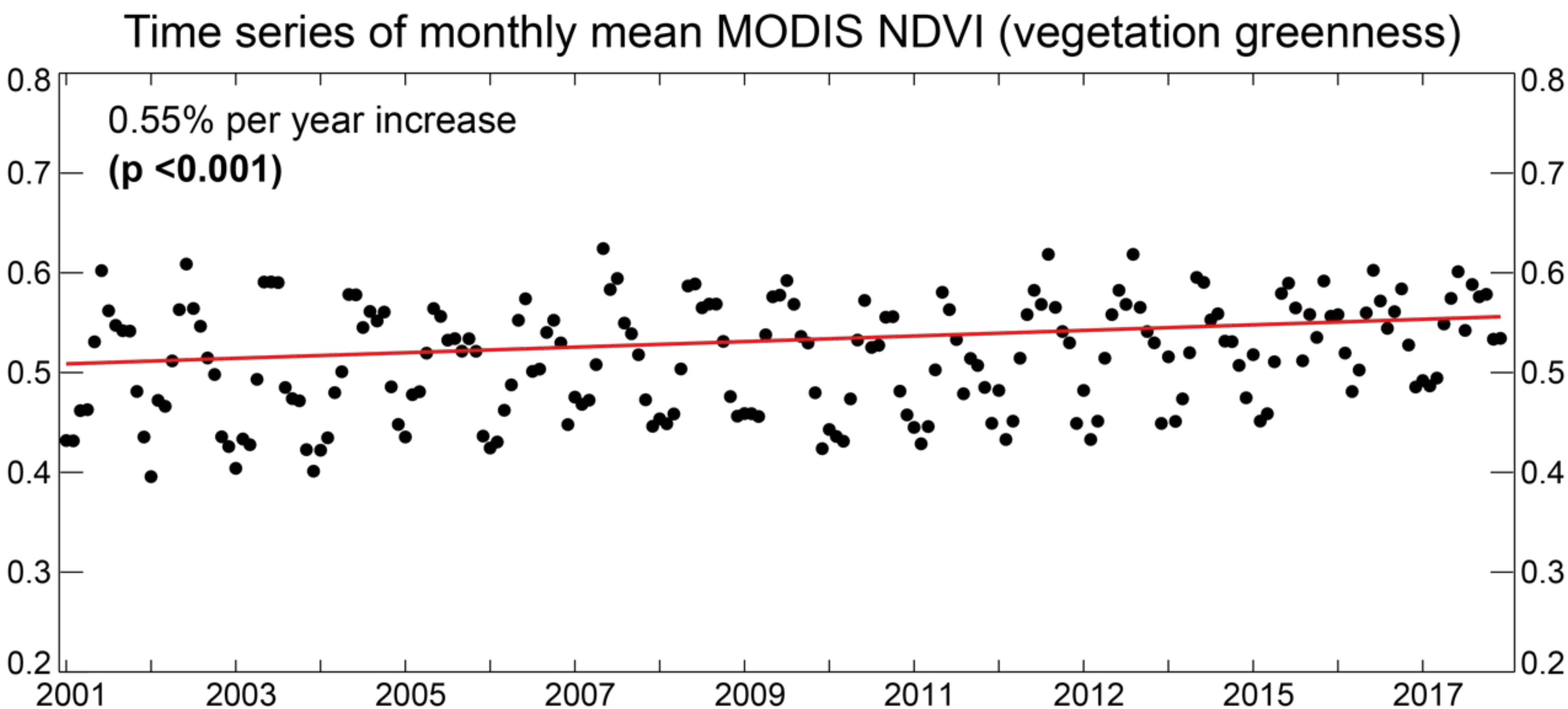
Initial Application to London

Decline in NO_2 over London similar to Birmingham



Still to be validated with surface observations

Birmingham Vegetation Greenness



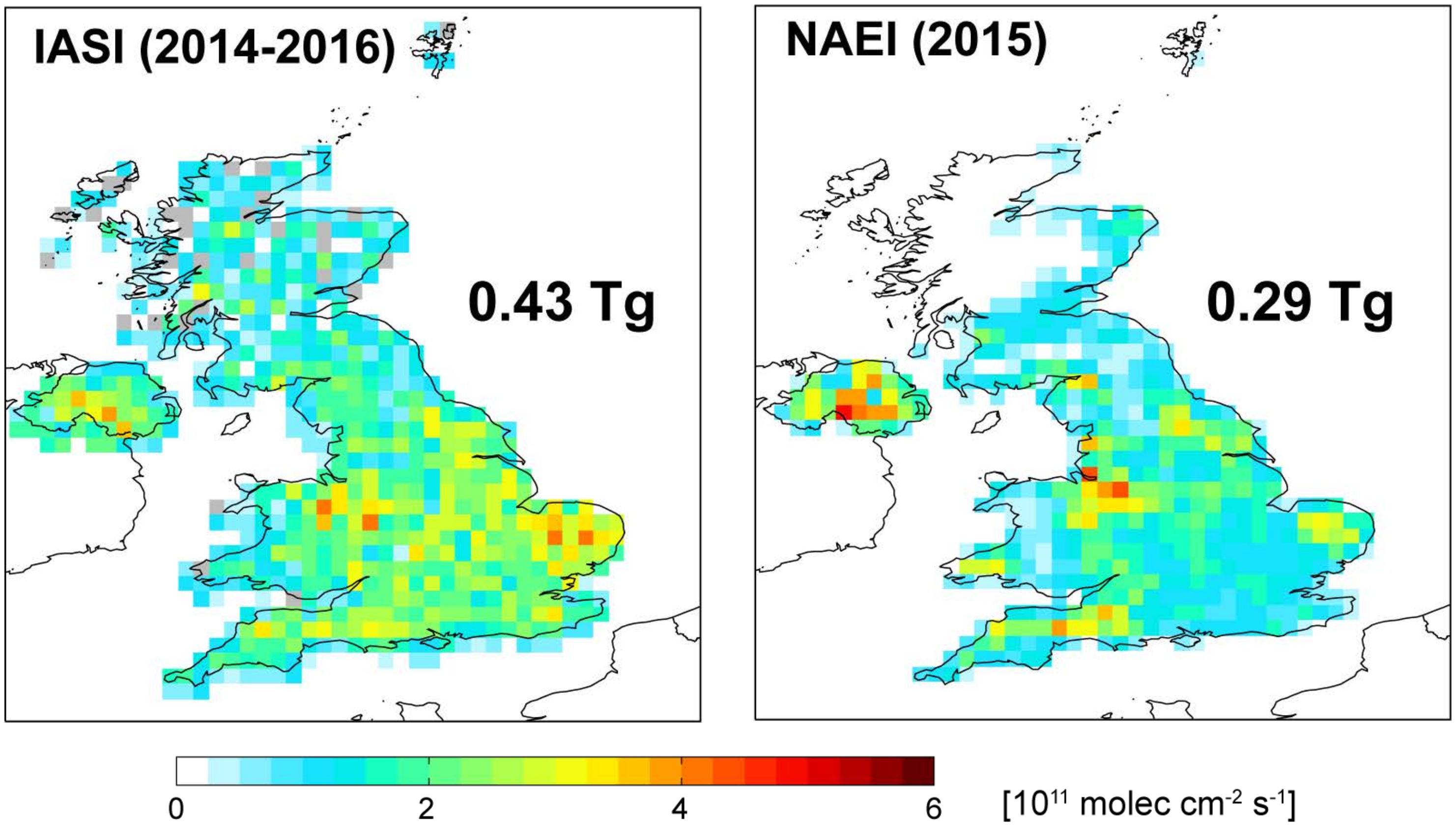
<u>Significant seasonal trends:</u> **1.1%** per year (**winter**), **0.61%** per year (**autumn**)

Implications for health of green spaces and ability to sequester carbon (climate change)

Constrain Emissions: Ammonia (NH_3)

Ammonia (NH_3) is a precursor of aerosols

<u>Agriculture</u> is the dominant source

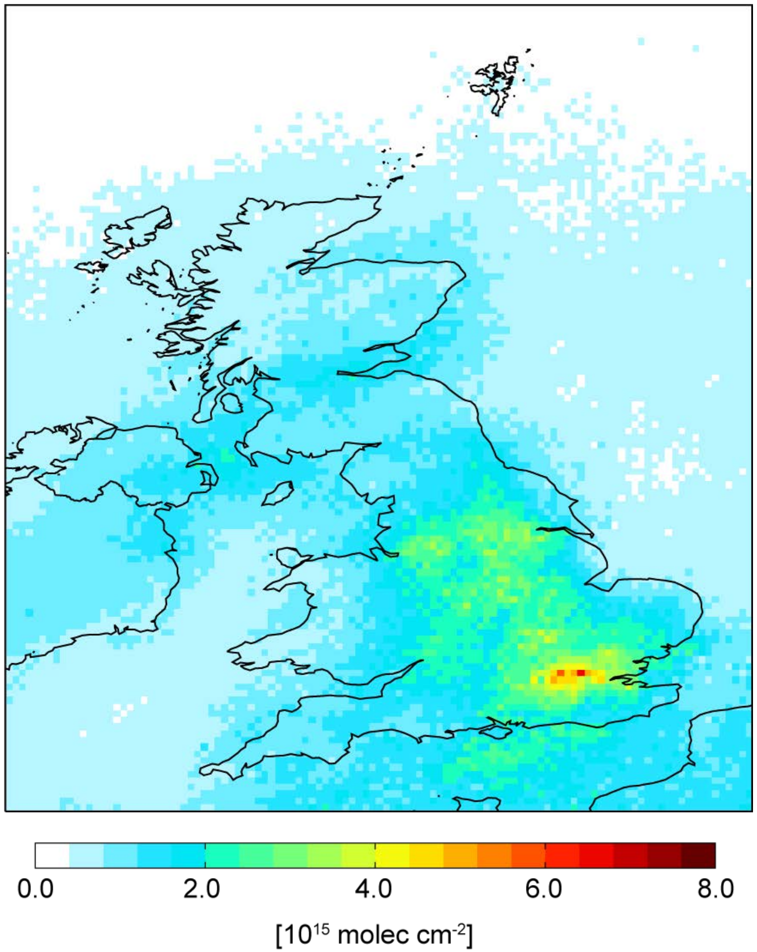


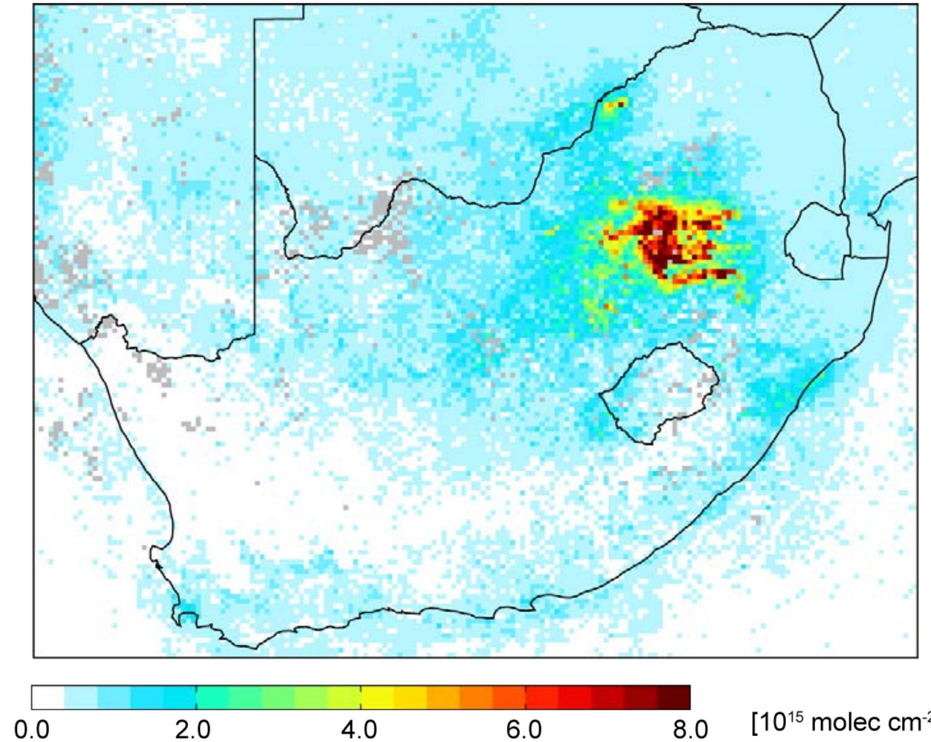
Spatial resolution: **0.25° × 0.25°**

Reasonable correlation: **R = 0.64**

Future Constraints on Emissions

TROPOMI NO_2 for July 2018





Data availability:
https://s5phub.copernicus.eu/dhus/#/home

0.1° × 0.1° (~10 km × 10 km) compared to 0.25° × 0.25° for OMI