Enhancing Air Quality Monitoring and Assessment in Africa and the UK with Earth Observations

Eloise Marais

with Alfred Bockarie and Karn Vohra

UNIVERSITY OF LEICESTER

UK Sources: Cars and Wood Burners

In 2.5 million homes in the UK

INDEPENDENT

Environment

Each car in London costs NHS and society £8,000 due to air pollution, report finds

'We know the health impacts of air pollution, and now the economic case for cleaning up the air we breathe has been laid bare'

Josh Gabbatiss Science Correspondent | @josh_gabbatiss | Wednesday 6 June 2018 00:13 | 27 comments

Annual Emission Checks Exclude NO_x

Ministry of Transport (MOT) test

Petrol

KwikFit
291 - 295 Bearwood Road
Smethwick
Birmingham
B66 4DP
VIEA number: V100933

Date: 06/09/2018 Time: 09:27:07
Odometer: Make:
VRN: FP54FLV Model:
Tester: H.Khan Engine Size: 1299 cc
Fuel Type: Petrol

MOT Exhaust Emissions Test Results

Basic Emission Test

Result			Diagnosis Limits	min	max
Fast Idle Test			Pass		
Engine Speed	= Manual Check		Pass	2500	3000
CO	= 0.01	% vol	Pass	-	0.20
HC	= 0	ppm	Pass	-	200
Lambda	= 1.003		Pass	0.970	1.030
Natural Idle Test			Pass		
Engine Speed	= Manual Check		Pass	450	1500
CO	= 0.00	% vol	Pass	-	0.30
OVERALL RESULT EXHAUST EMISSIONS TEST			Pass		

Engine oil temperature check:Temperature gauge showed warm engine
Engine speed measurement by-passed

Page 1 of 1

Diesel

VTS Name:
VTS Address:

VTS No.:

Date & Time: 27/6/2014 15:21 Tester ID: G SAUNDERS
MOT No.: [redacted] VRM: [redacted]
Make: AUDI Model: A4
VIN: Size (cc):

Dieseltune - Diesel MOT Smoke Test program | Program - Version 1.1.14.0

MOT SMOKE TEST - Fast Pass

RESULT			DIAGNOSIS	LIMITS Min	Max
Oil temperature	= No engine temperature taken			60	-
Smoke Reading					
Peak 1	= 0.10	m^{-1}		-	-
Zero Drift	= 0.00	m^{-1}	PASS	-	0.10
Average	= 0.10	m^{-1}			
MOT Test Result					
Fast Pass	= 0.10	m^{-1}	PASS	-	1.50

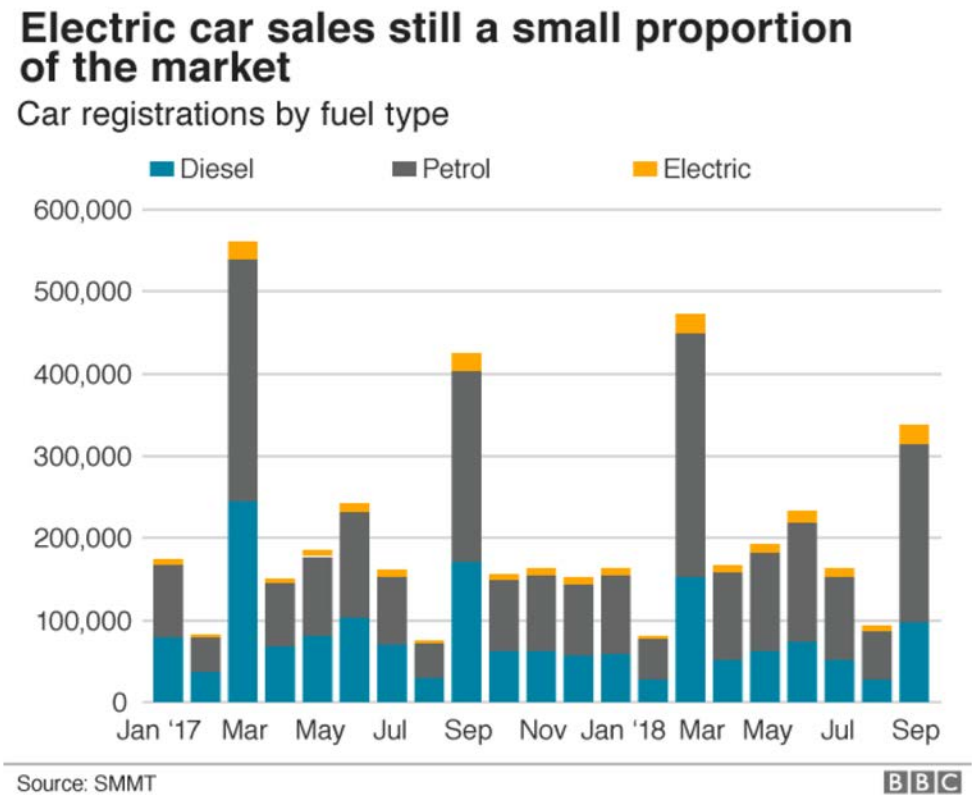
DIESELTUNE Dieseltune Smoke Analysis
© Dieseltune 2003 - 2010

Diesel and Petrol Ban

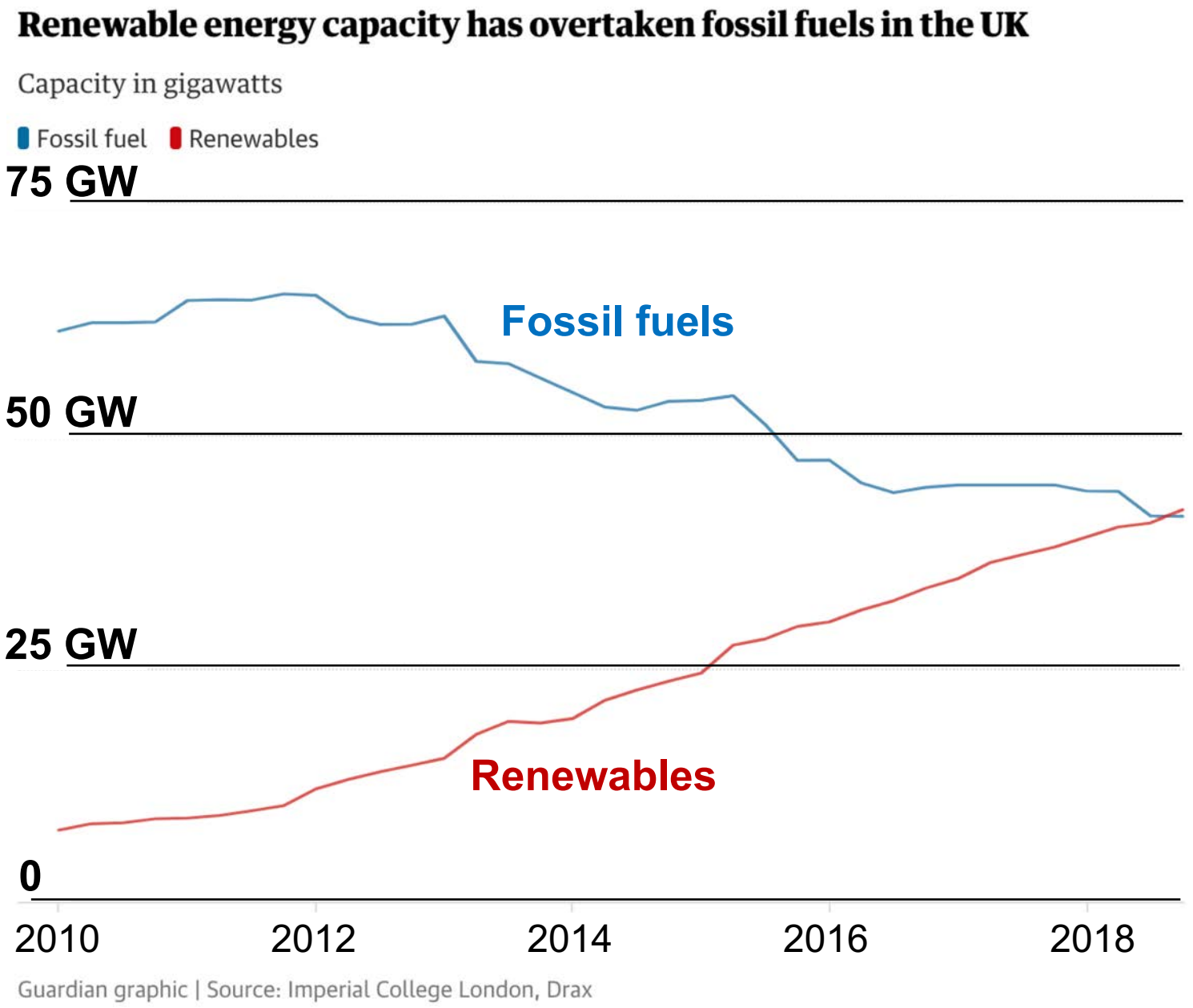
BBC NEWS

ll new cars in the UK will be "effectively zero emission" by 2040, under lans to tackle air pollution.

ne government is under pressure to bring forward this deadline and ban all sa new petrol and diesel cars by 2032, **after a report by a parliamentary ommittee described its plans as "vague and unambitious"**.



UK Renewables Surpass Fossil Fuels

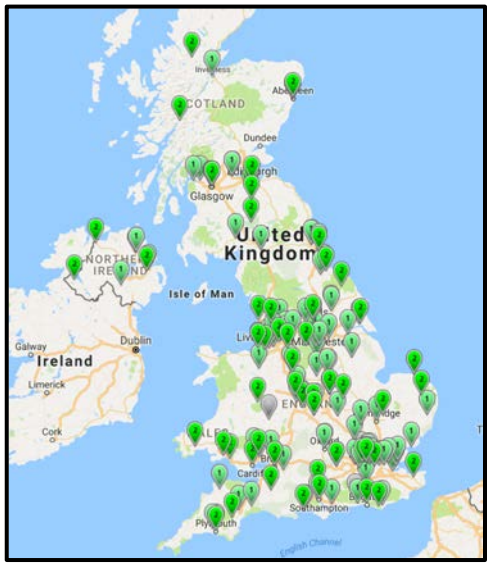


UK Air Quality Monitoring

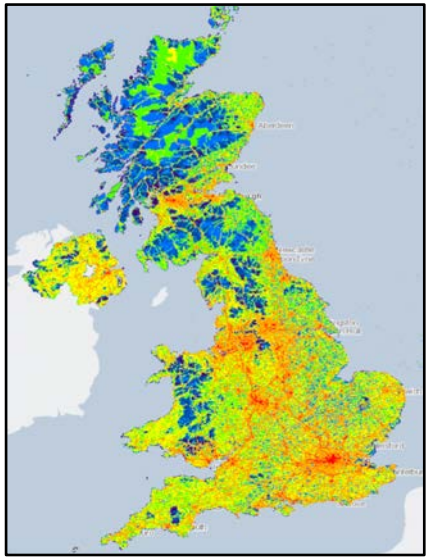
Current Approach:

- Surface monitoring network
- National Atmospheric Emission Inventory (NAEI)
- Air quality models
- Entities: Environment Agency, local city councils, universities, Environmental Consultants

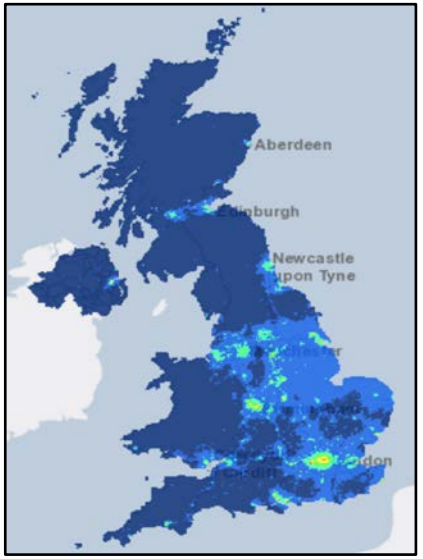
Network



Emissions



Models



UK Air Quality Monitoring

Shortcomings:

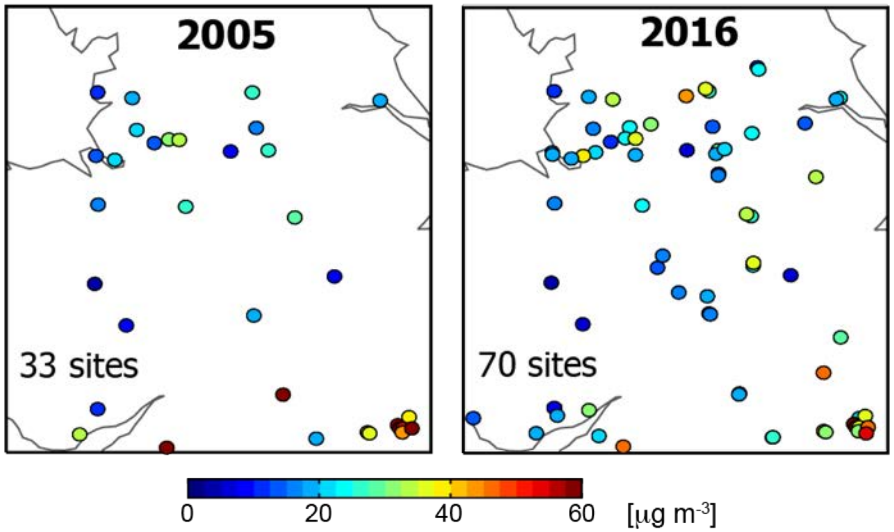
- **Austerity** (need to do more with less)
- **Costly** (£52k-£173k per monitor)
- **Laborious**
- **Large gaps** (space, time, frequency, pollutants)
- NAEI **inconsistent** from year-to-year
- **Limited validation** (large uncertainties)

Impacts efficacy of policy and leads to large fines (>£60M)

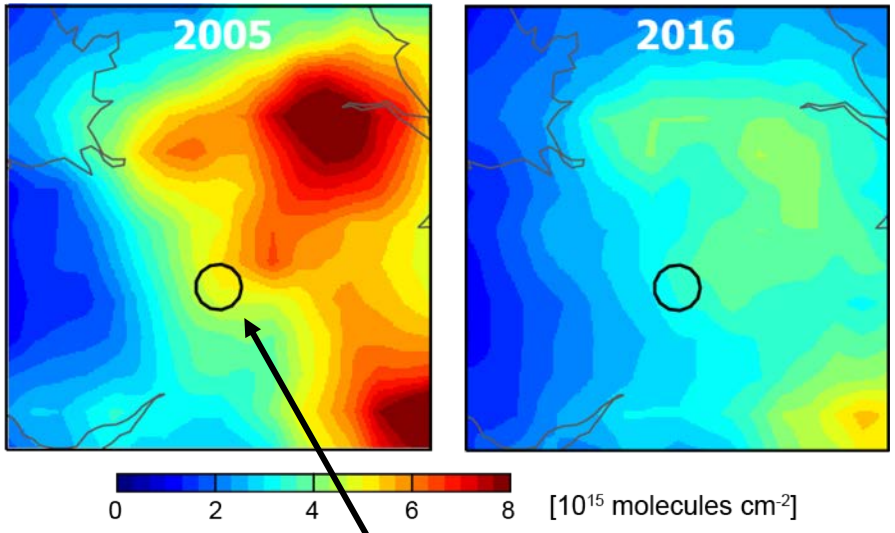
UK Air Quality Monitoring

Earth observations are the only viable solution to address data gaps!

DEFRA (surface) NO_2



Aura OMI (EO) NO_2



Excludes city council measurements

Birmingham:

3% per year decline in NO_2

Demands advanced skills to use and interpret, limited in-house expertise

Tool for Recording and Assessing the City Environment

TRACE

A data transformation and interpretation service to integrate Earth observations in air quality policy

NERC SCIENCE OF THE ENVIRONMENT

EPSRC Engineering and Physical Sciences Research Council

CATAPULT Satellite Applications

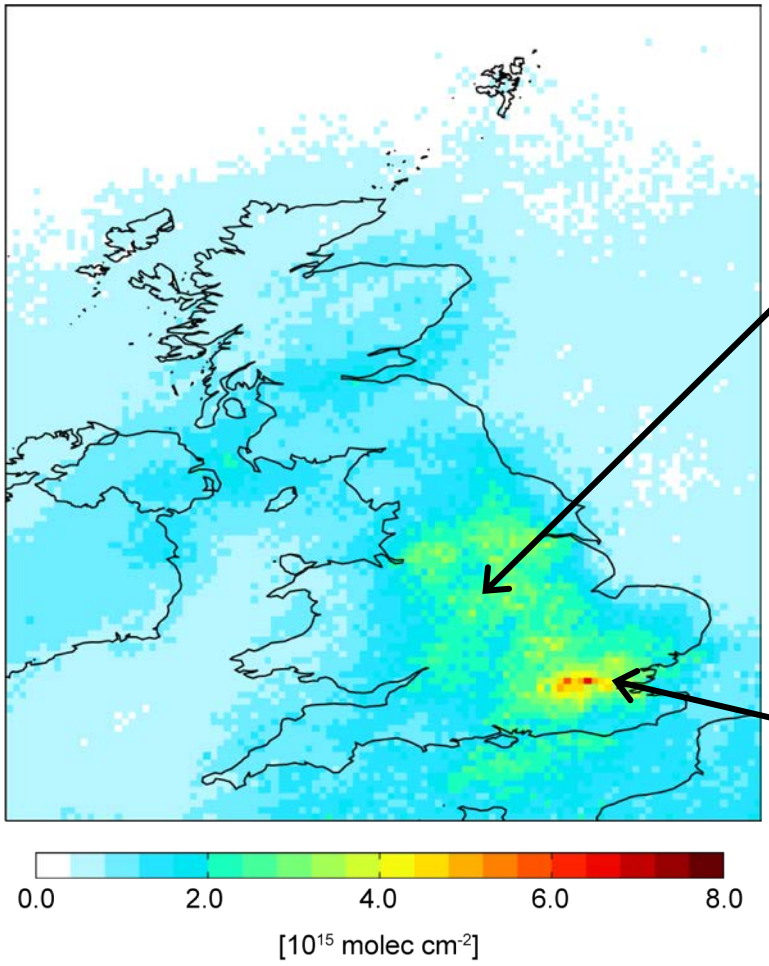
Birmingham City Council

defra Department for Environment Food and Rural Affairs

Validation over UK Cities

Do satellites reproduce temporal variability of surface air pollution?

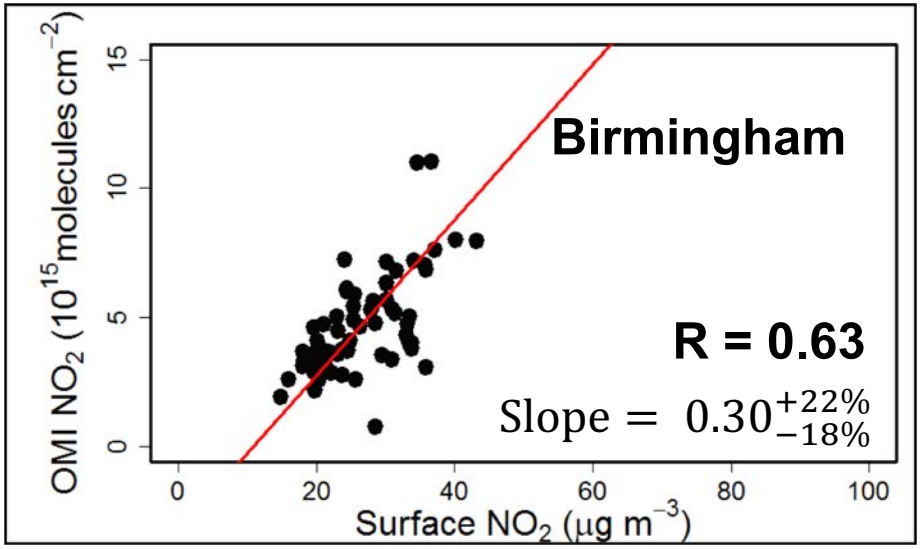
UK TROPMI NO_2



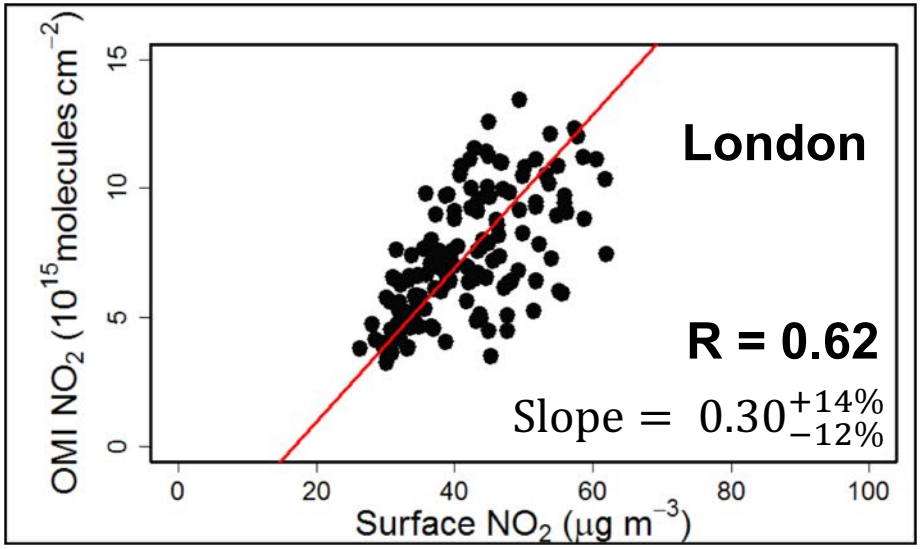
Validation over UK Cities

Demonstrate validity of satellite observations

Validation of Ozone Monitoring Instrument (**OMI**) NO_2 with surface measurements



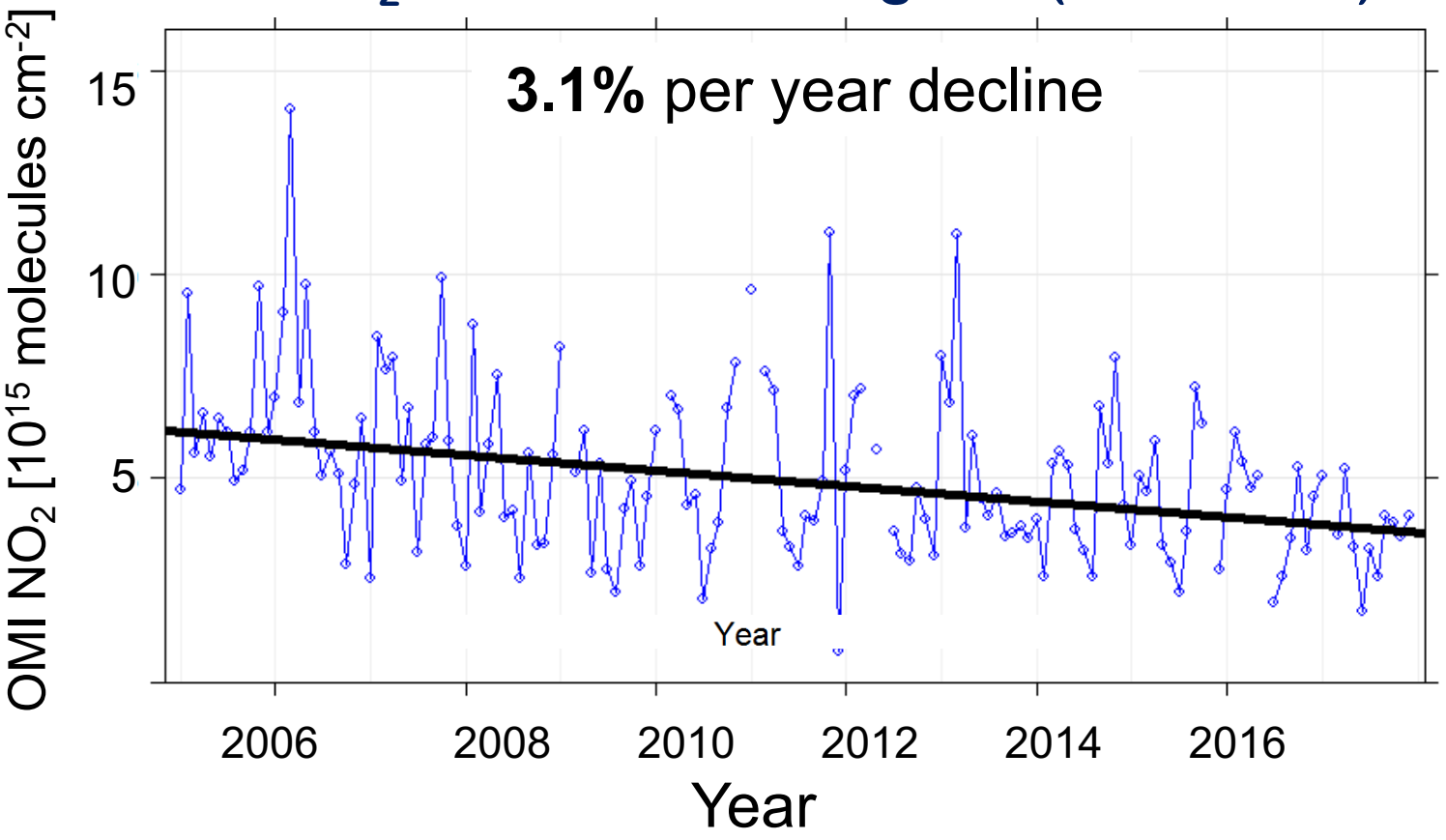
March 2011 – September 2016



January 2005 – April 2018

Supported use of satellite observations to estimate long-term trends

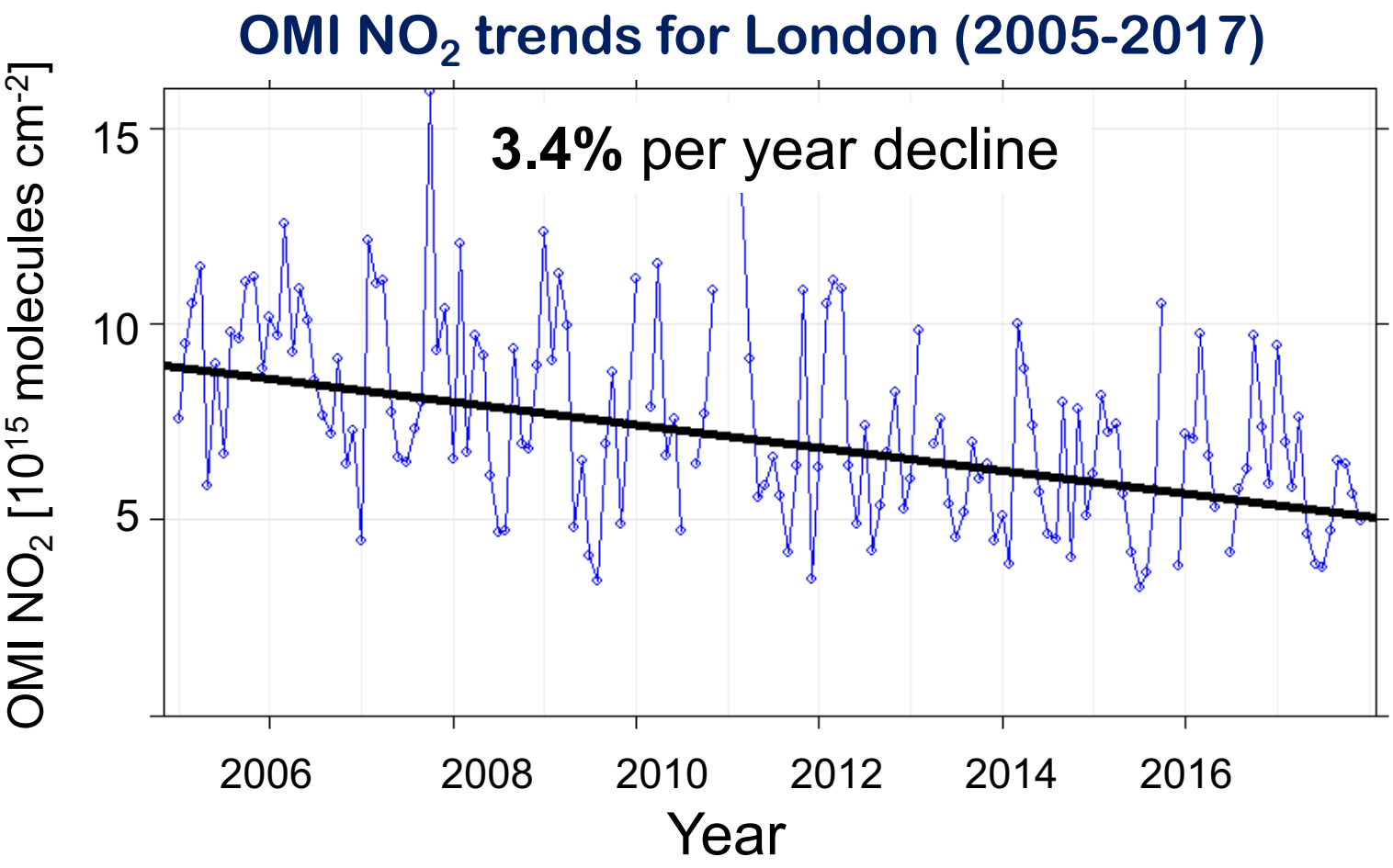
NO_2 trends in UK Cities



40% decline in NO_2 (and NO_x emissions) over the satellite record

Not feasible to infer a trend with the surface network

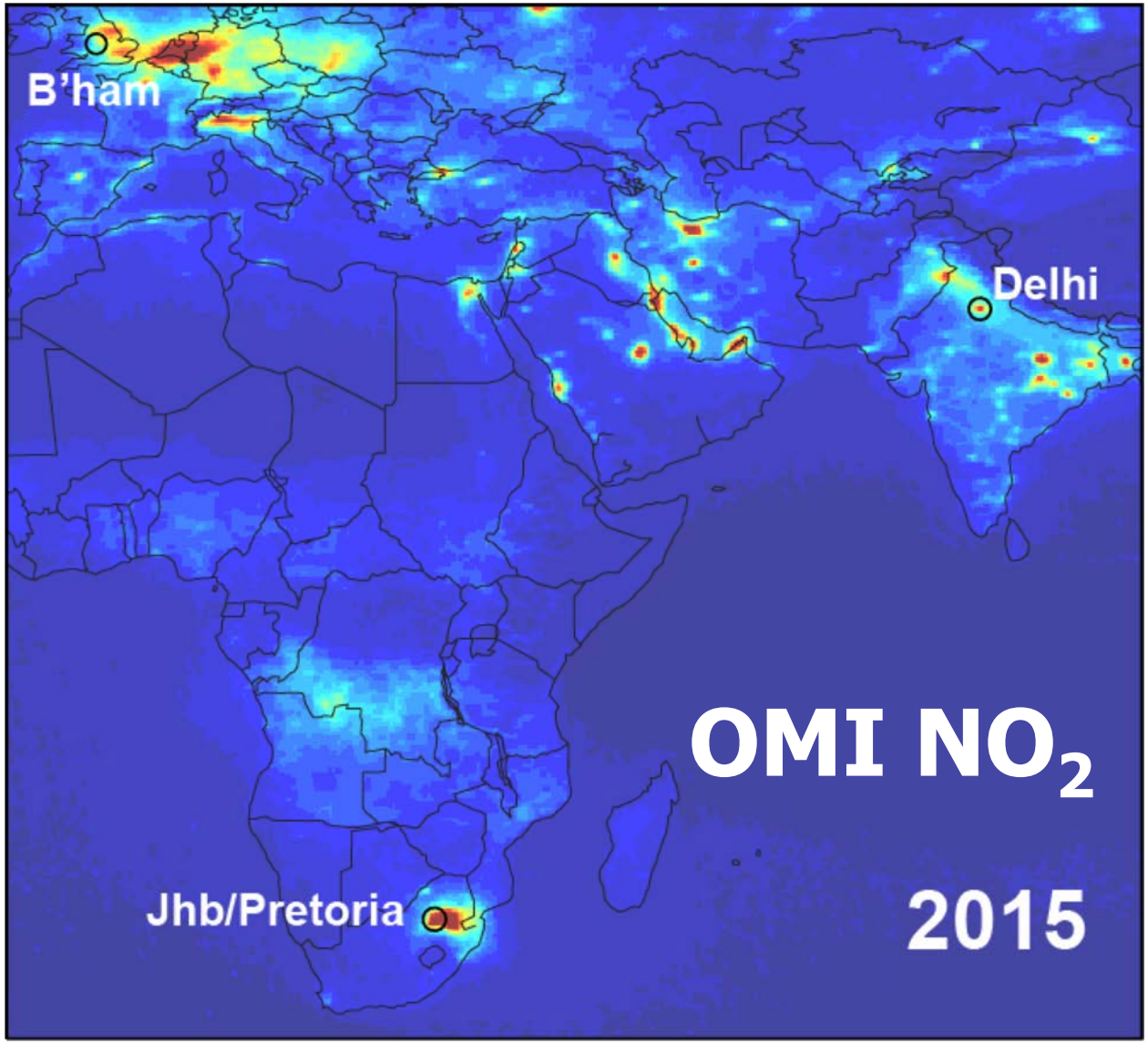
NO_2 trends in UK Cities



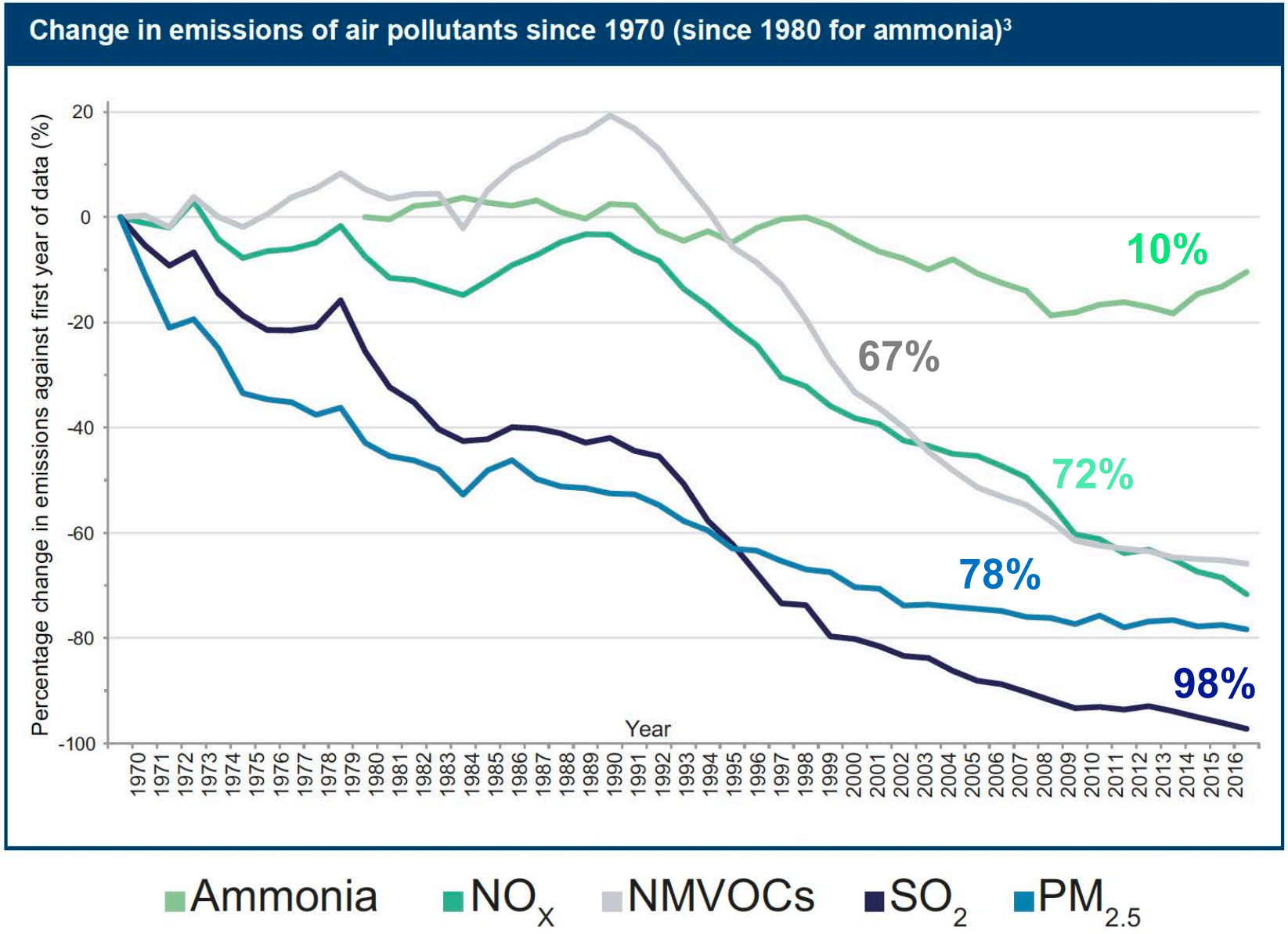
44% decline in NO_2 (and NO_x emissions) over the satellite record

Trend from the **surface network** is only **-1.8% per year**
(almost half that from the satellite record)

Validate and Estimate Trends in India and South Africa



NH_3 Increasingly Important in the UK

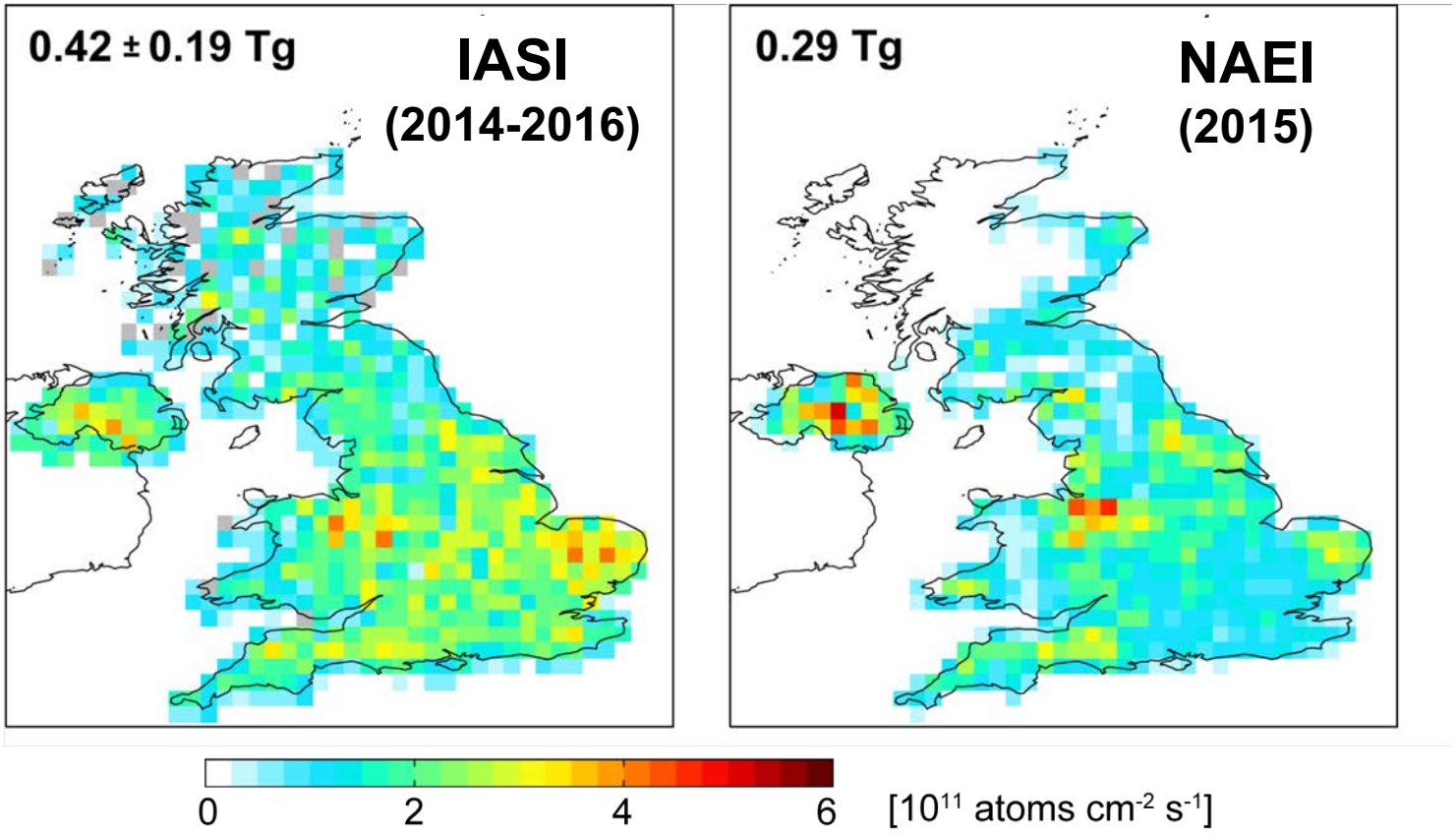


[DEFRA Clean Air Strategy, 2018]

NH_3 Emissions Across the UK

Ammonia emissions derived with the IASI instrument and GEOS-Chem

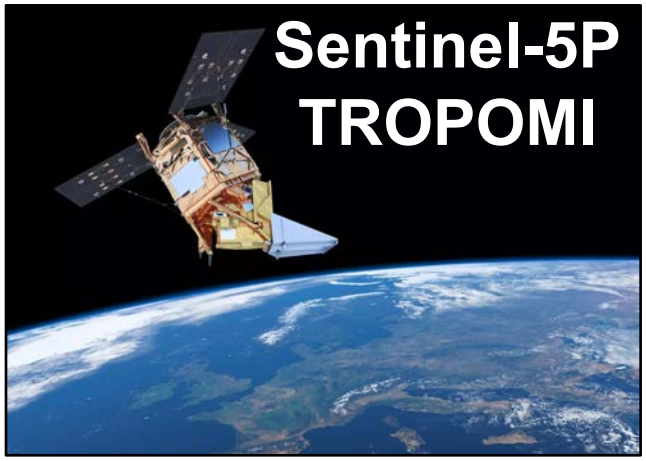
Annual Ammonia Emissions



[IASI from M Van Damme and P.-F. Coheur at ULB]

Satellite-derived ammonia emissions almost double the NAEI

Exploit high spatial resolution of TROPOMI

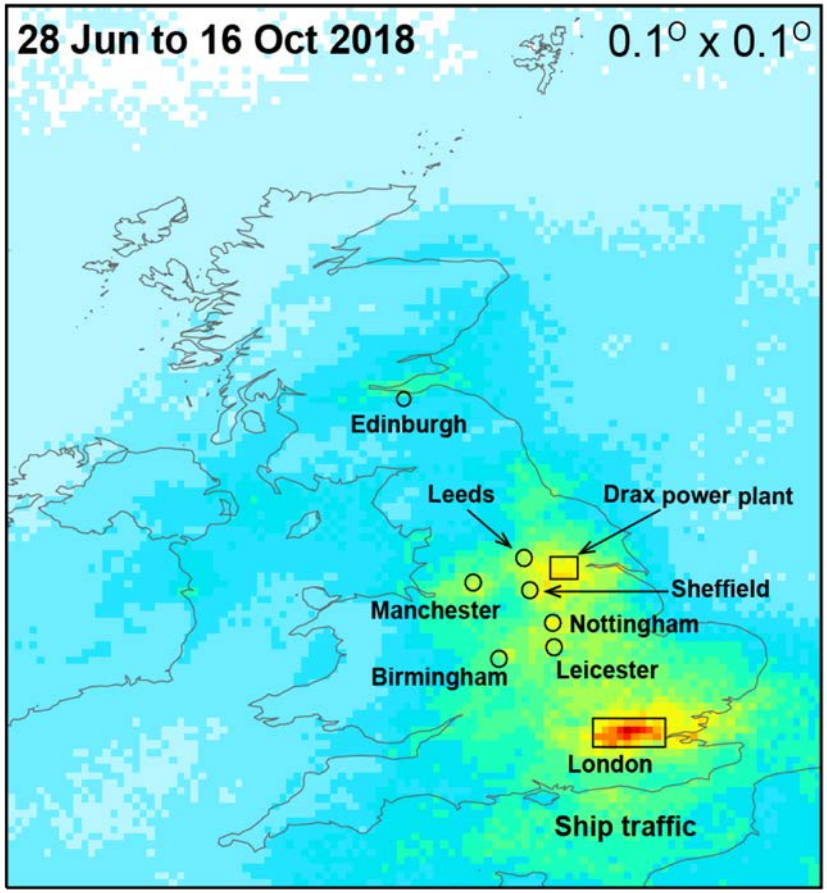


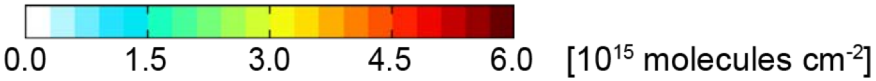
Overpass	13h30 LT	13h30 LT
Compounds	NO_2, O_3, HCHO, SO_2 CHOCHO, AI, AOD	Same as OMI + CH_4 and CO
Resolution	13 km × 24 km	7 km × 3.5 km

Constrain spatial variability of pollutants and evaluate high-resolution air quality monitoring tools (models and inventory)

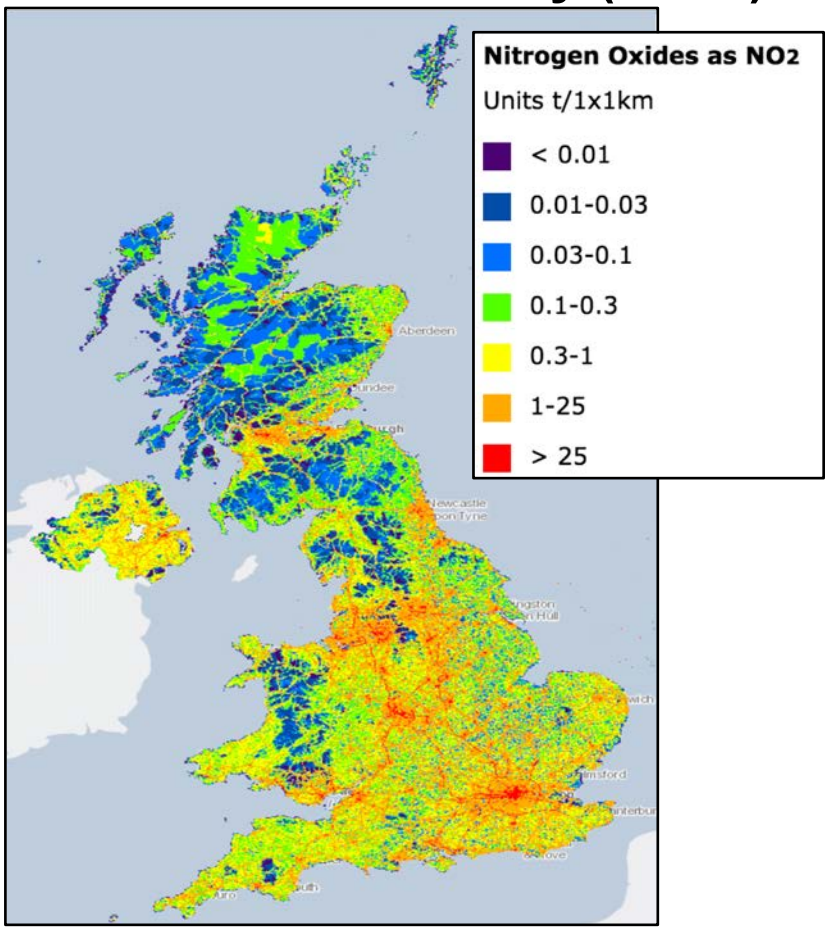
Exploit high spatial resolution of TROPOMI

TROPOMI NO_2 over the UK





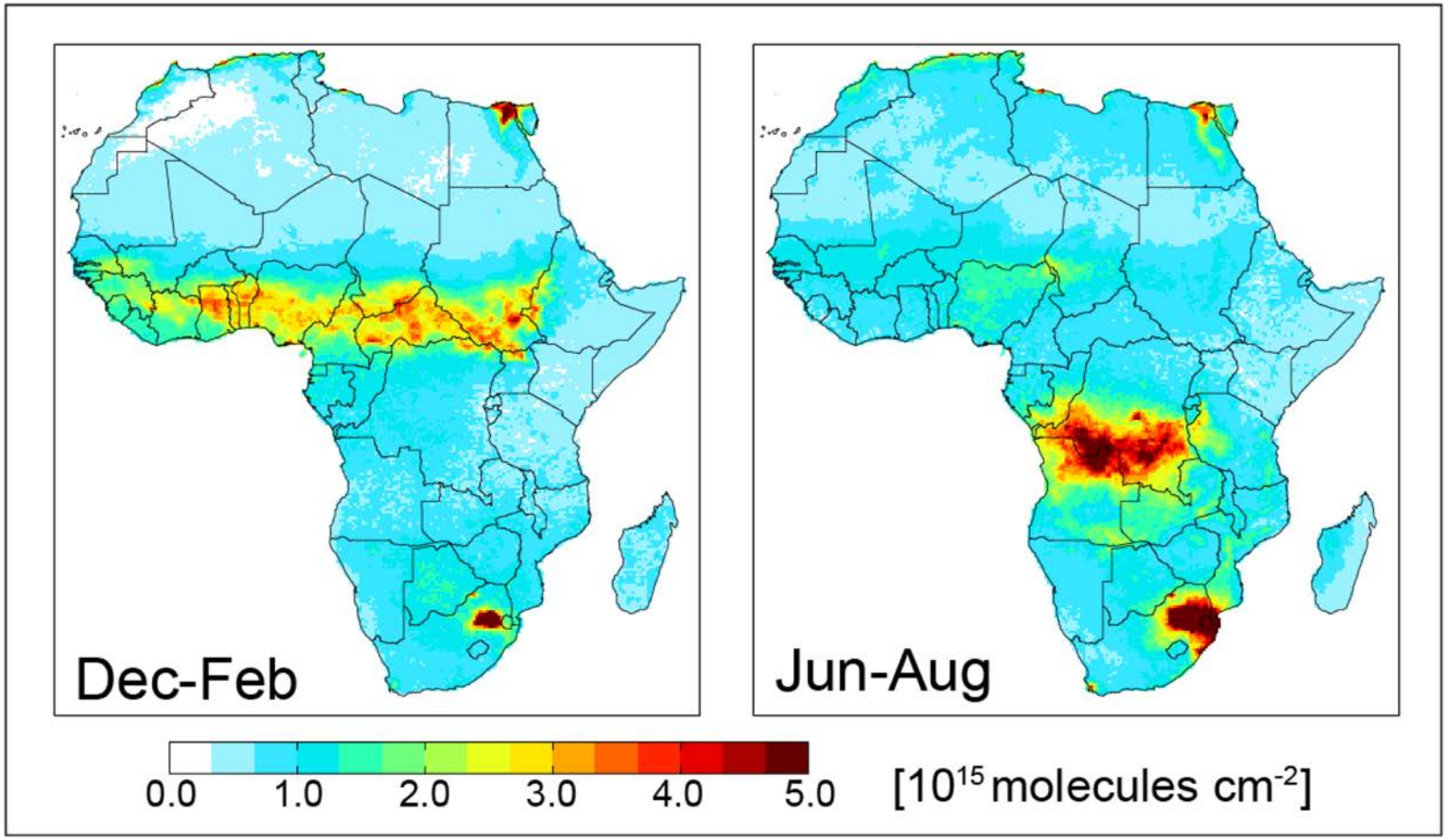
National Atmospheric Emission Inventory (NAEI)



Evaluate high-resolution emission inventory and air quality models

More challenging to do in Africa

Seasonal mean tropospheric NO_2 column densities for 2006-2007

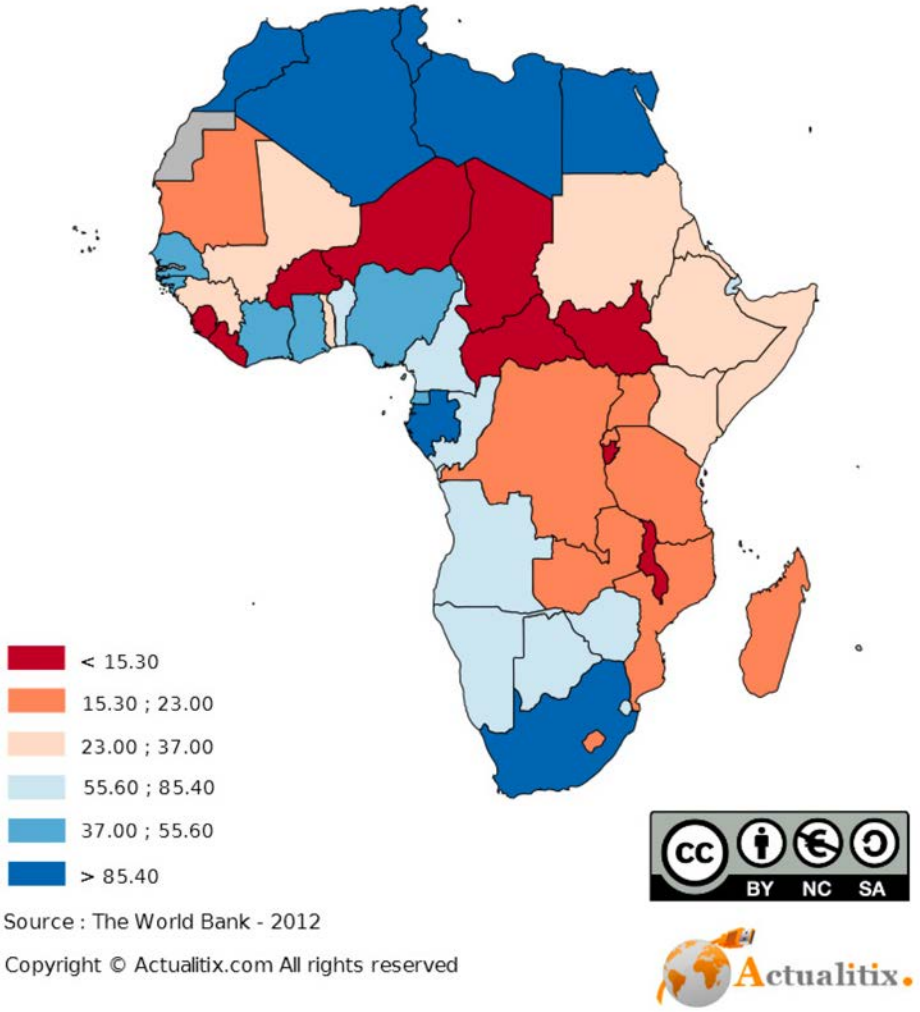


[Marais and Chance, 2015]

Anthropogenic sources dominated by **diffuse**, **inefficient combustion**

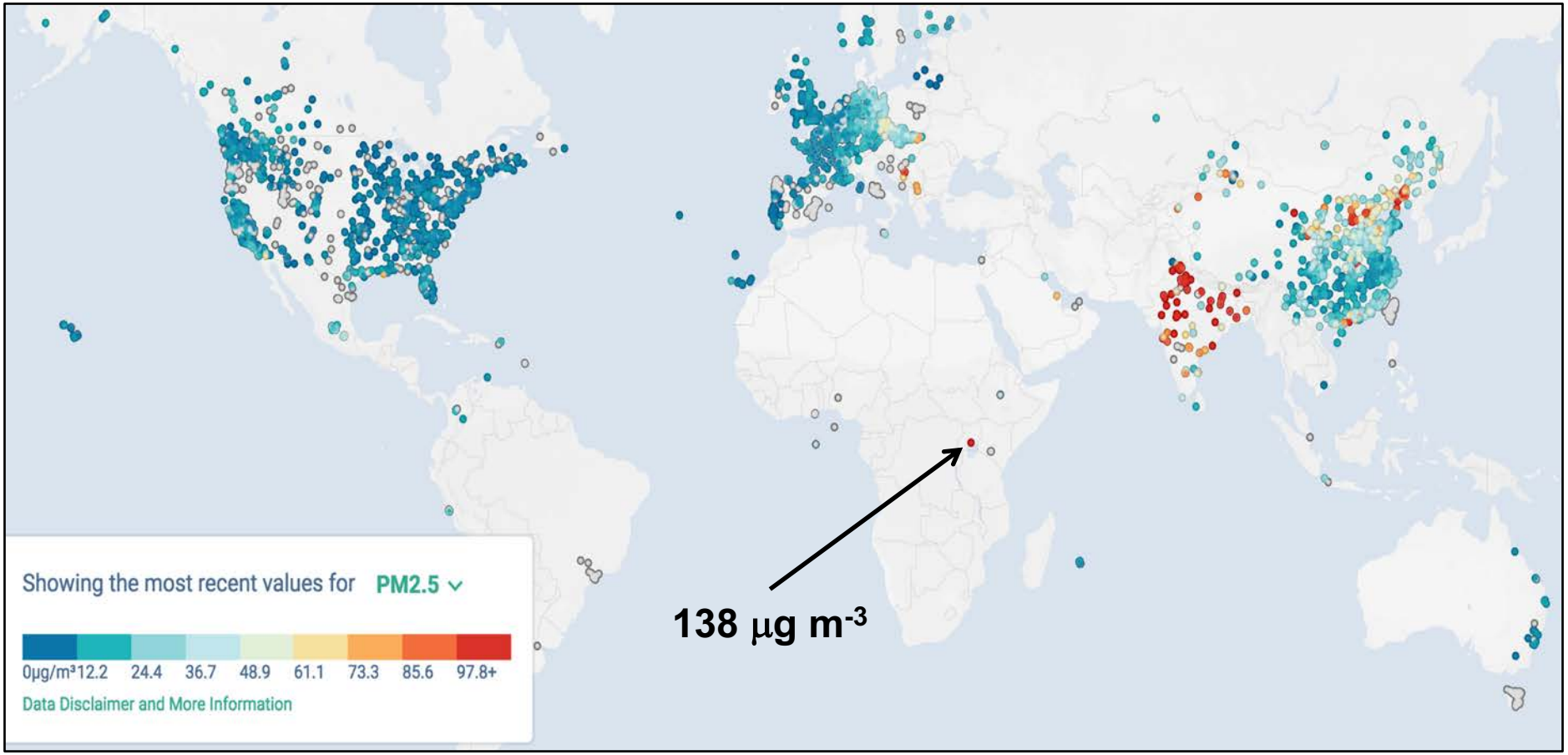
Limited Access to On-Grid Electricity

Access to Electricity (% of population)



Varies from >85% for South Africa to <15% for Chad/Niger/Malawi

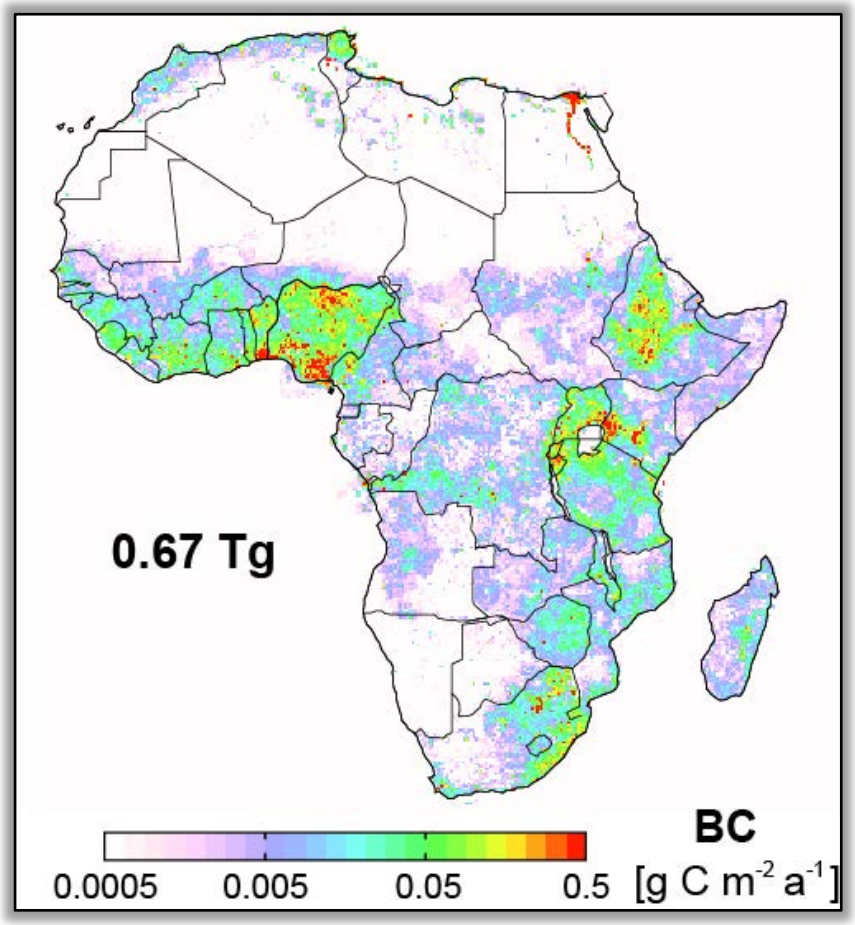
Severely Limited Surface Measurements



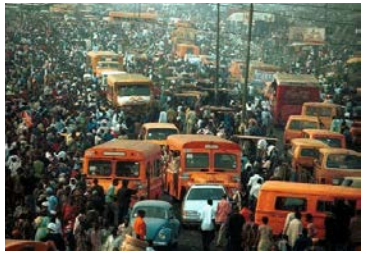
[OpenAQ, Accessed 7 November 2018]

Diffuse and Inefficient Combustion Emissions (DICE-Africa)

Black Carbon

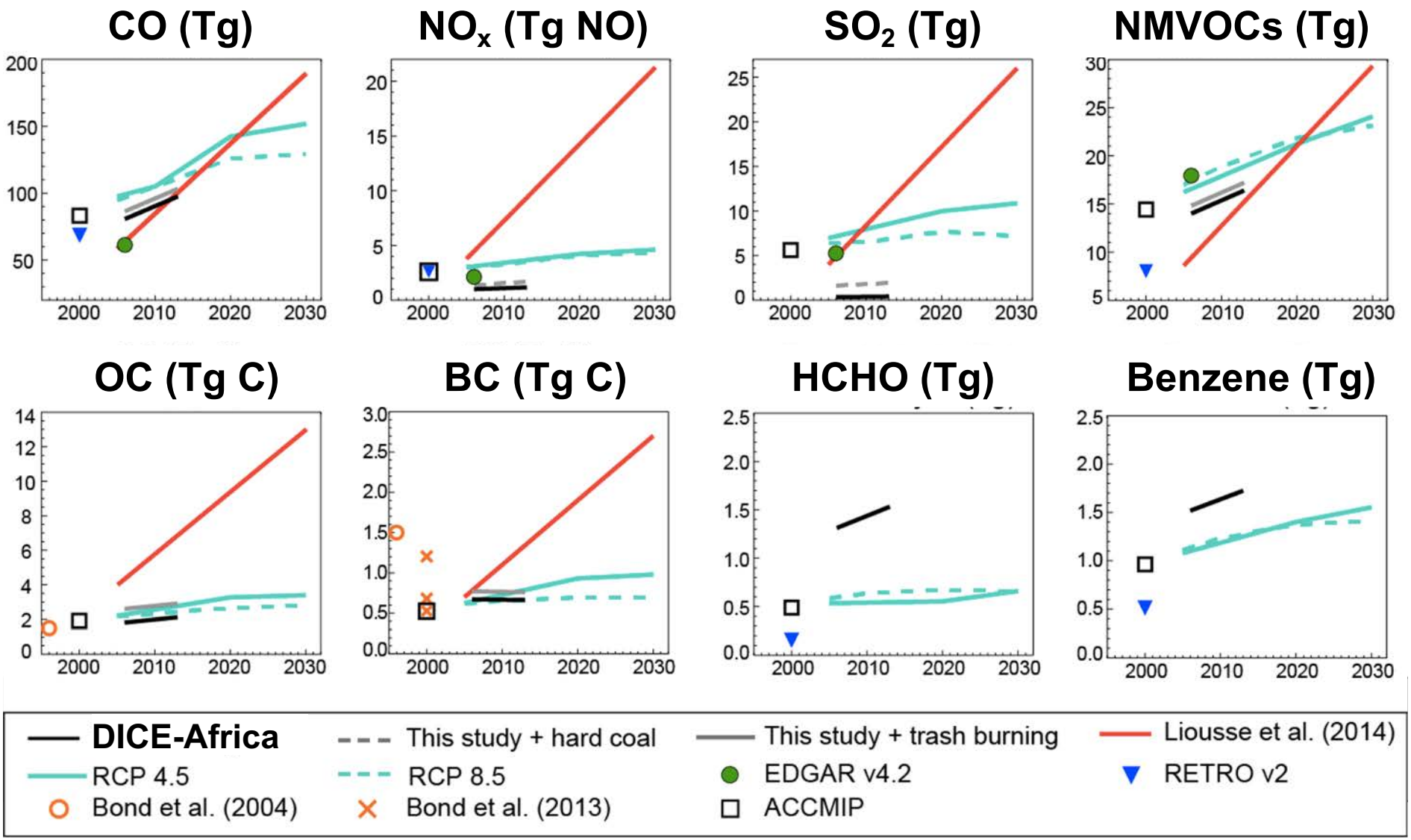


[Marais and Wiedinmyer, 2016]



DICE and open fire emissions similar for many pollutants

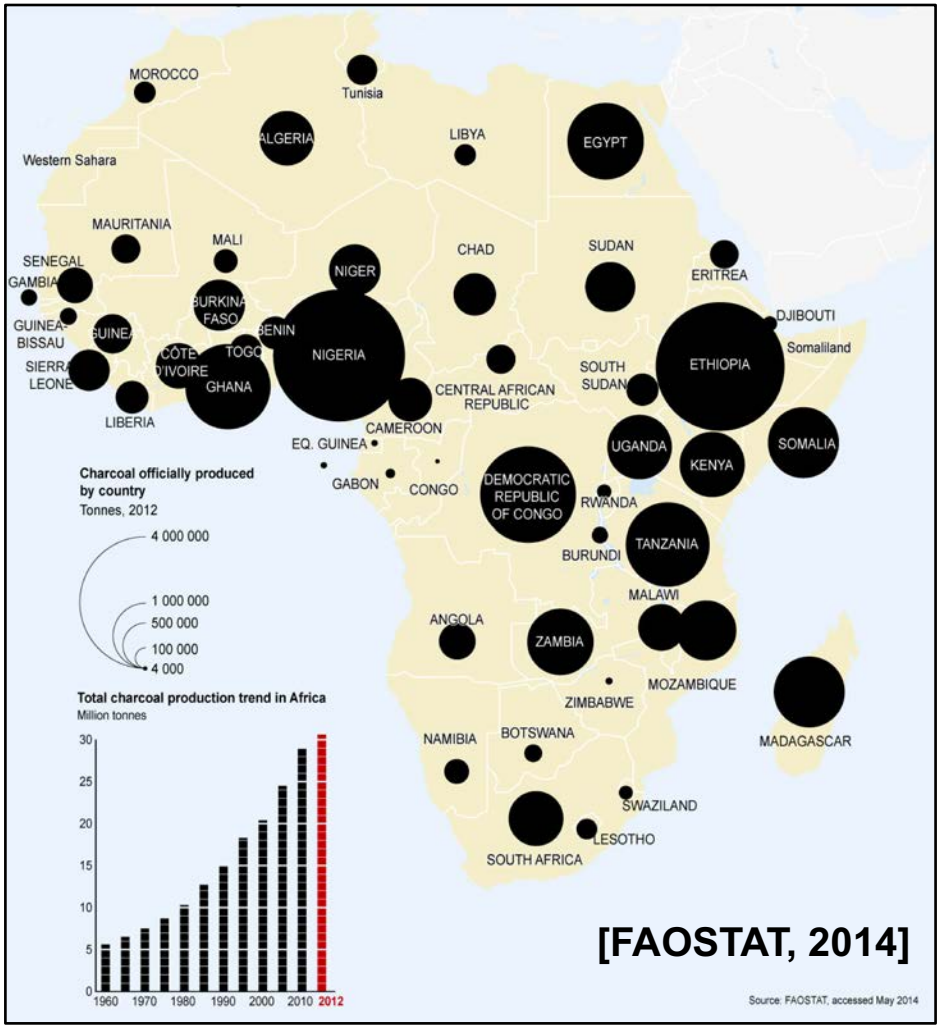
Emissions Trends and Projections for Africa



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

A Focus on Charcoal Production

Charcoal Production in Africa



6-9% per year increase in production

Major export in Somalia fueling civil unrest there

Improved representation of charcoal emissions

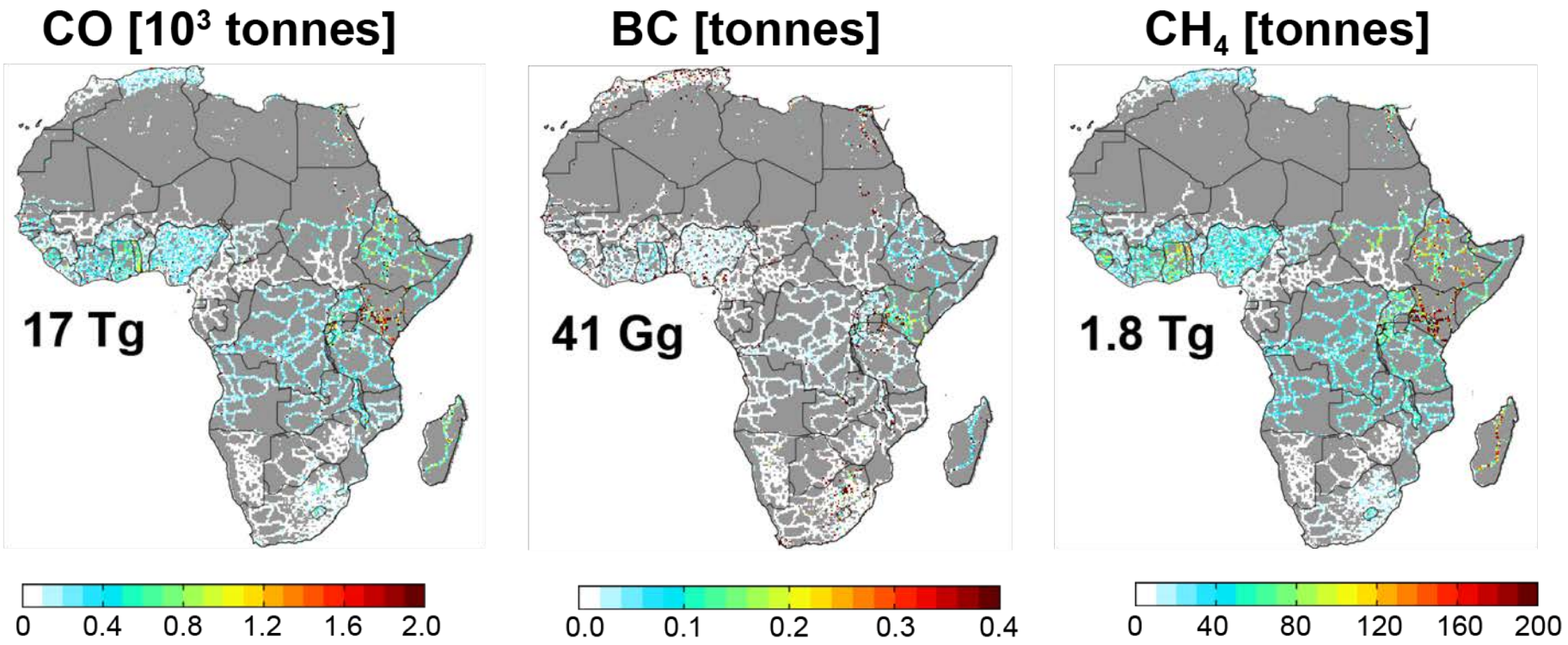
Production (RURAL)

Transport

Use (URBAN)

Improved representation of charcoal emissions

Pollutant emissions from charcoal production, use and transport



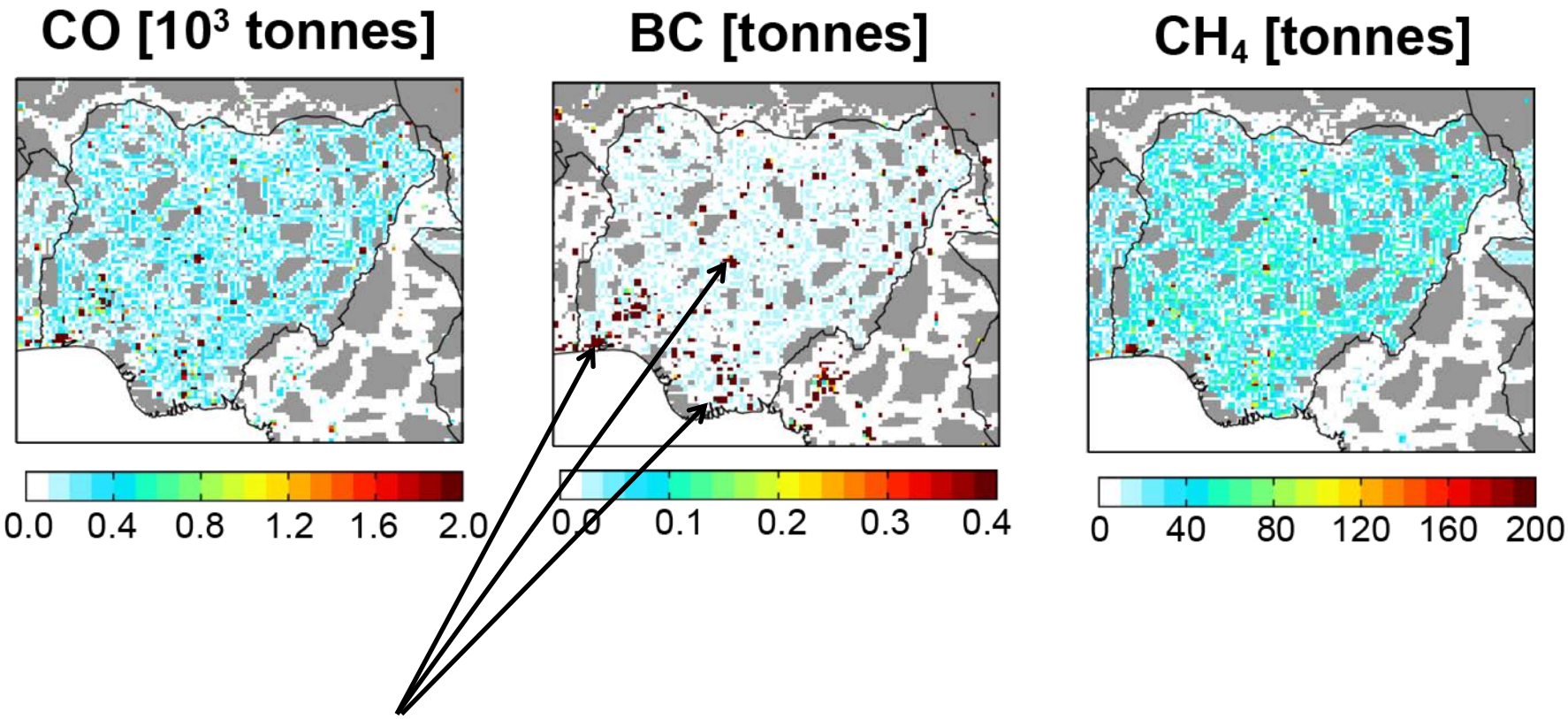
Annual biomass burning emissions in Africa:

440 Tg CO; **2.6 Tg BC**; **15 Tg CH_4** [Y. Shi et al., 2015]

We don't account for burning of plastic to sustain the fire.

Improved representation of charcoal emissions

Zoom in to Nigeria (largest charcoal producer in Africa)



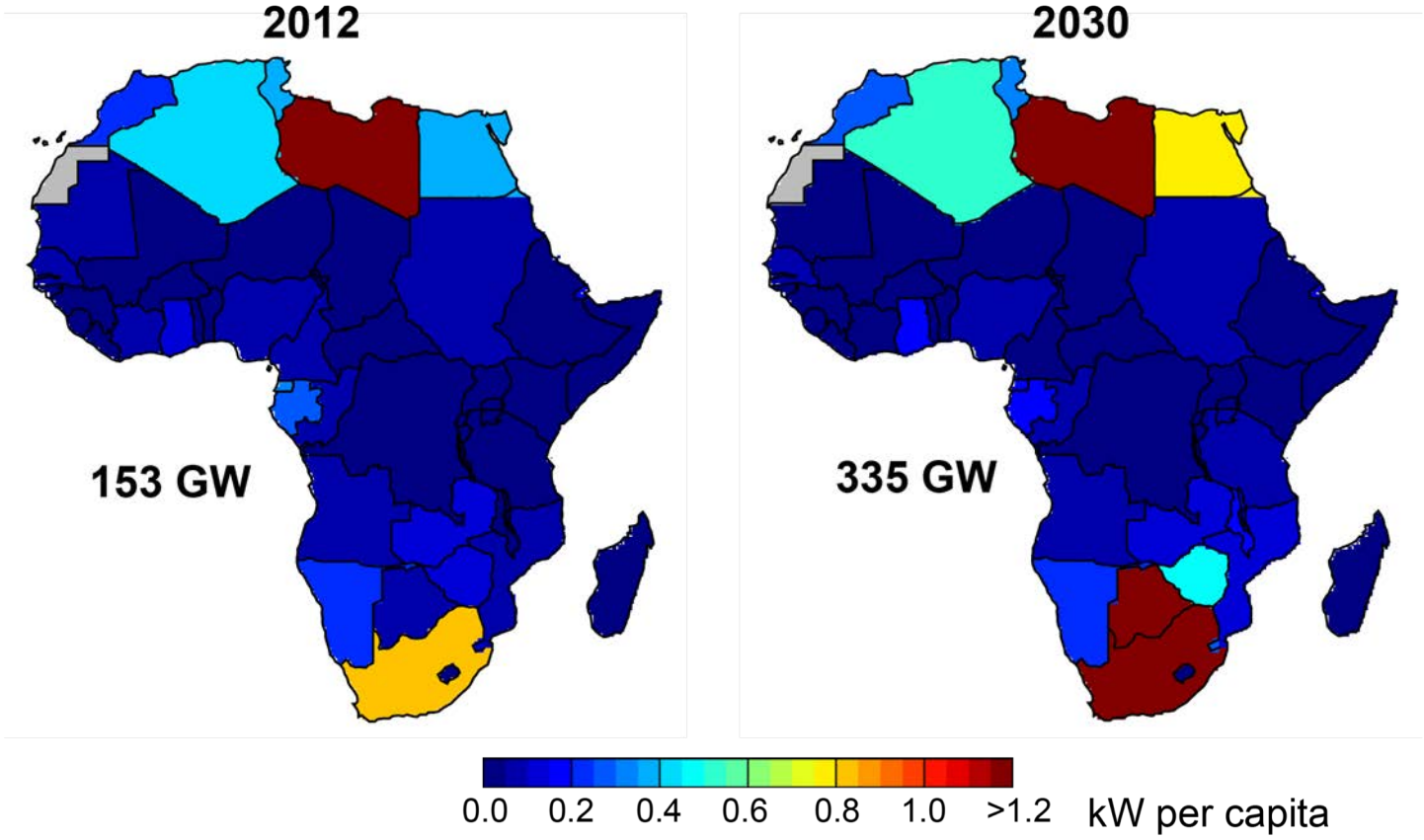
Question we'd like to answer with this inventory:

Is charcoal production in Africa sustainable?

Future Fossil Fuel Impact on Health

with R. F. Silvern, L. J. Mickley, A. Vodonos, J. Scwhartz

Per capita generating capacity



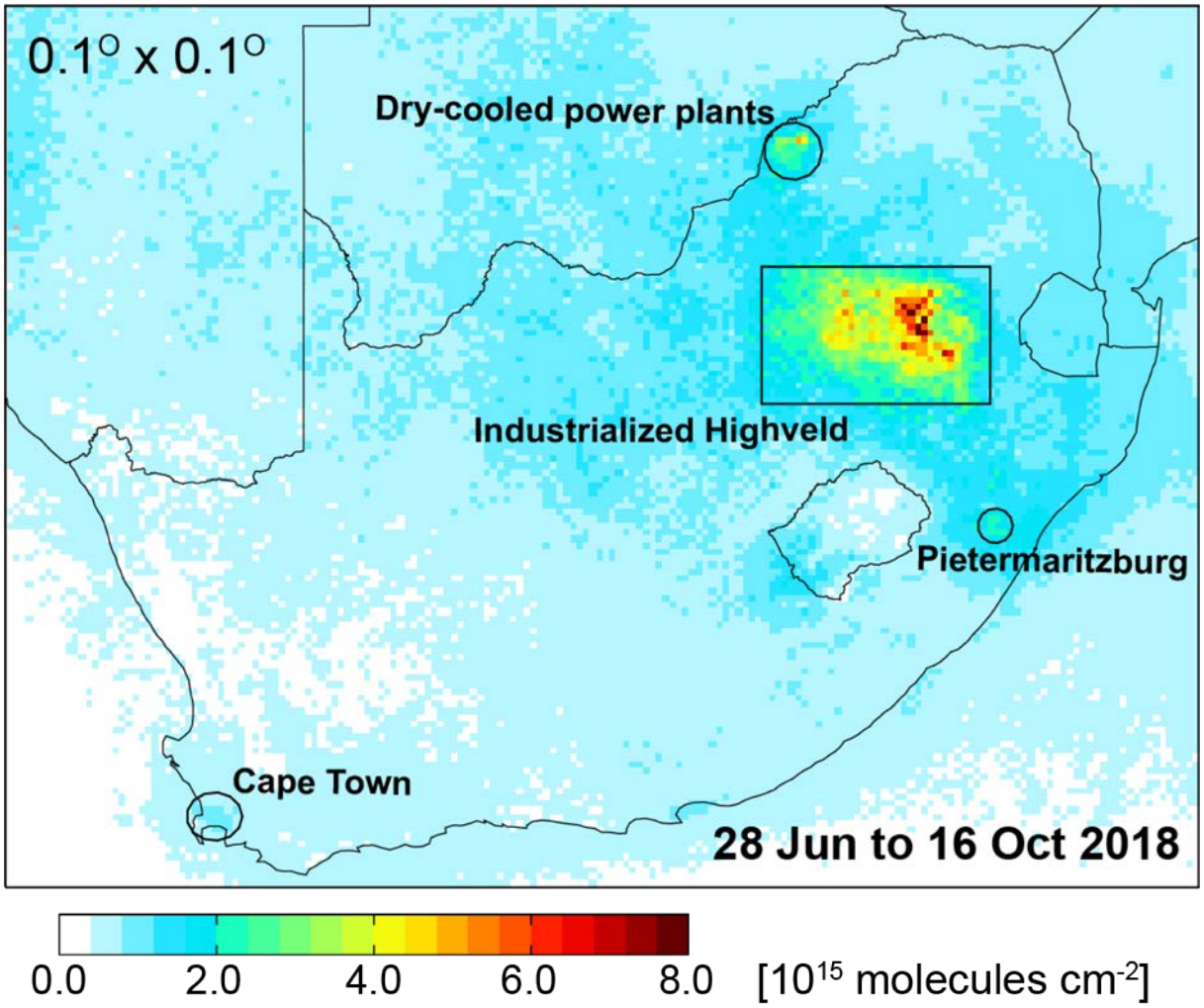
2012-2030 **installed capacity** increase: 120%

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

The Wallace Foundation®

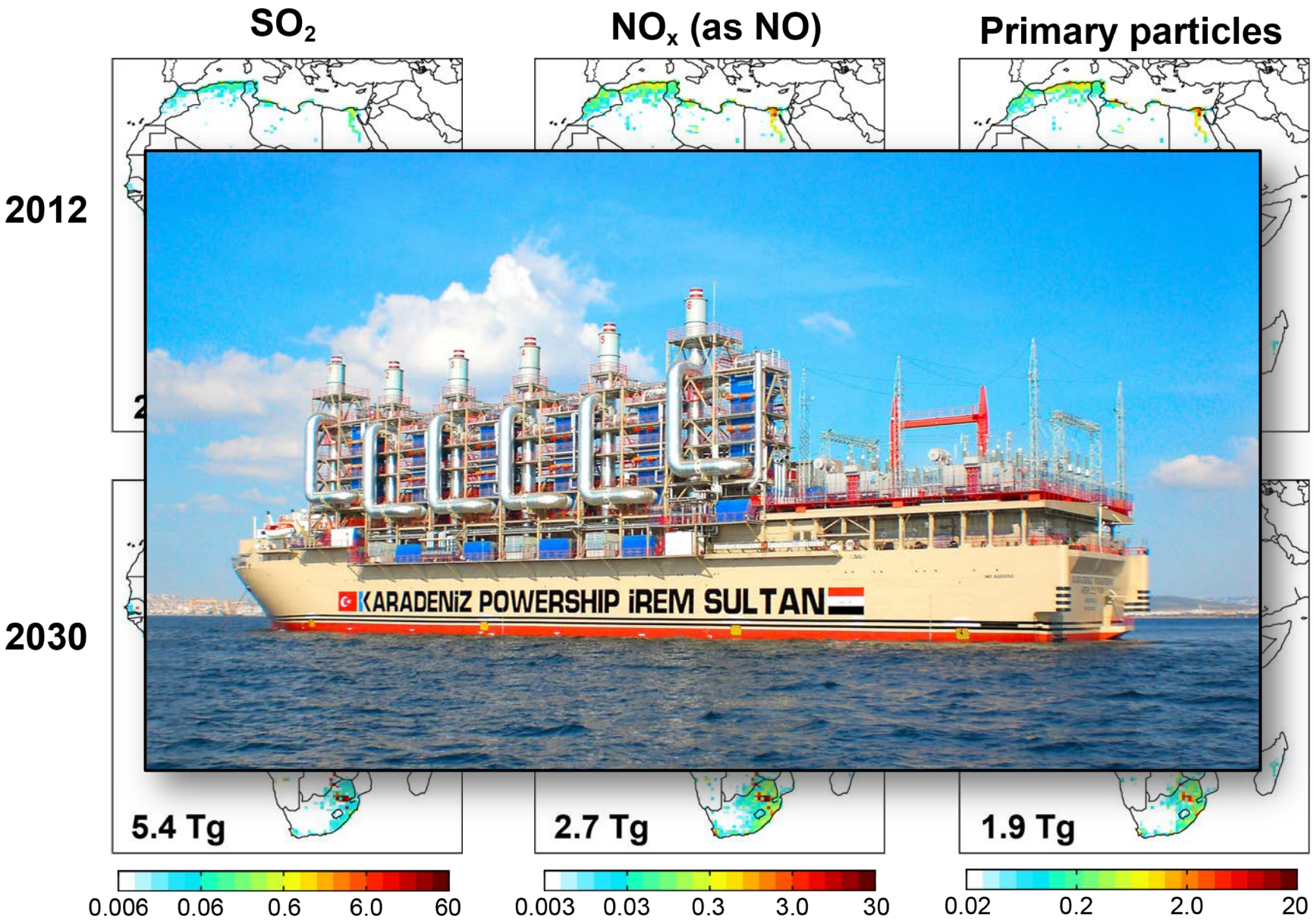
Even Challenging with TROPOMI

TROPOMI NO_2 over South Africa



NO_2 enhancements from dry-cooled power plants in South Africa

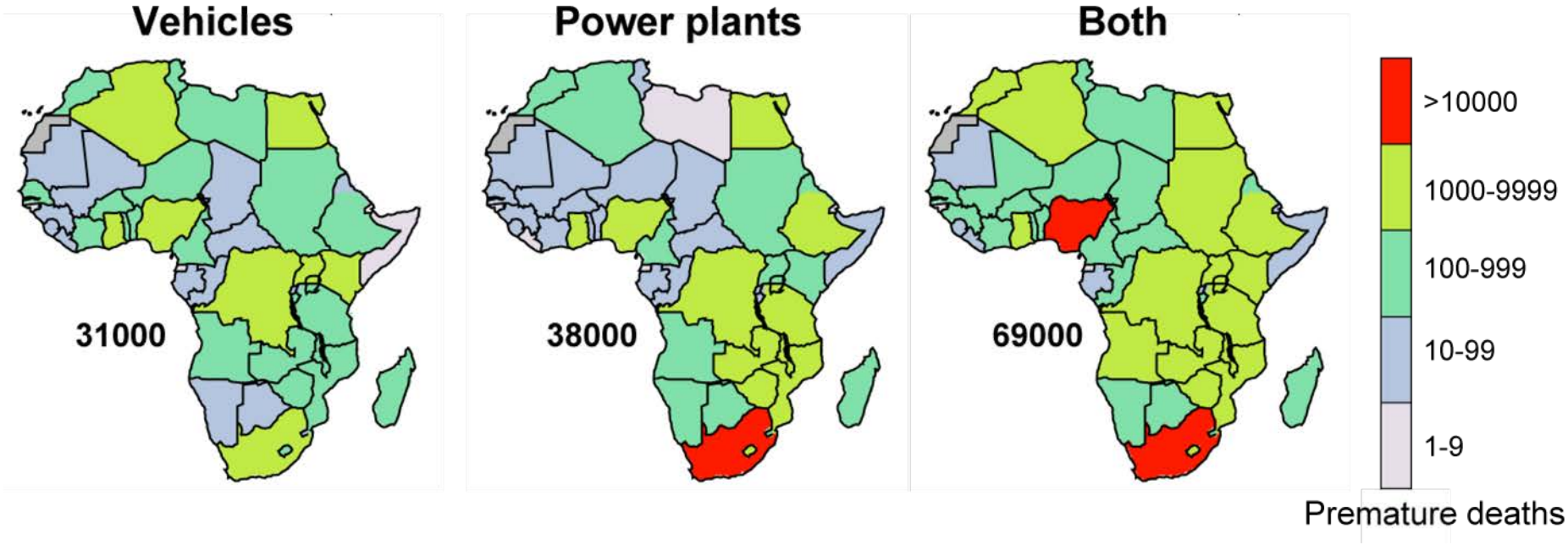
Air Pollution Emissions (g m^{-2} a^{-1})



Emission development by **Rachel Silvern**, Harvard

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

Acknowledgements

Graduate Students

Collaborators / Support

CATAPULT Satellite Applications

CATAPULT Future Cities

Birmingham City Council

defra Department for Environment Food and Rural Affairs

RICARDO

UK Funding Agencies

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