

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



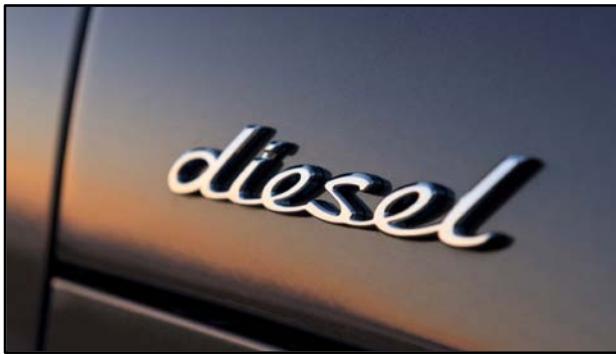
Eloise Marais

with Alfred Bockarie and Karn Vohra



UNIVERSITY OF
LEICESTER

UK Sources: Cars and Wood Burners



 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



Car name: KwikFit
Car address: 291 - 295 Bearwood Road
Smetwick
Birmingham
B66 4DP
VIEA number: V100933

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

MOT Exhaust Emissions Test Results
Basic Emission Test

Result	Diagnosis Limits		
	min	max	
Fast Idle Test			
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			
Engine Speed	= Manual Check	Pass	450 1500
CO	= 0.00	% vol	Pass - 0.30
OVERALL RESULT EXHAUST EMISSIONS TEST			
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.: VRM:
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
Oil temperature	= No engine temperature taken	Min 60 Max -
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

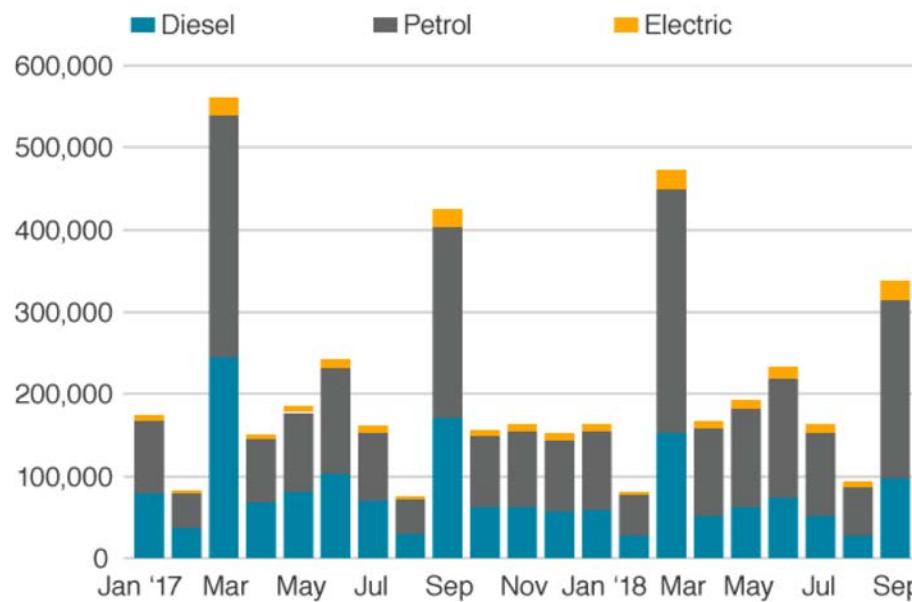
BBC NEWS

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

The government is under pressure to bring forward this deadline and ban all sales of new petrol and diesel cars by 2032, after a report by a parliamentary committee described its plans as "vague and unambitious".

Electric car sales still a small proportion of the market

Car registrations by fuel type



Source: SMMT

BBC

UK Renewables Surpass Fossil Fuels

Renewable energy capacity has overtaken fossil fuels in the UK

Capacity in gigawatts

■ Fossil fuel ■ Renewables

75 GW

50 GW

25 GW

0

Fossil fuels

Renewables

2010

2012

2014

2016

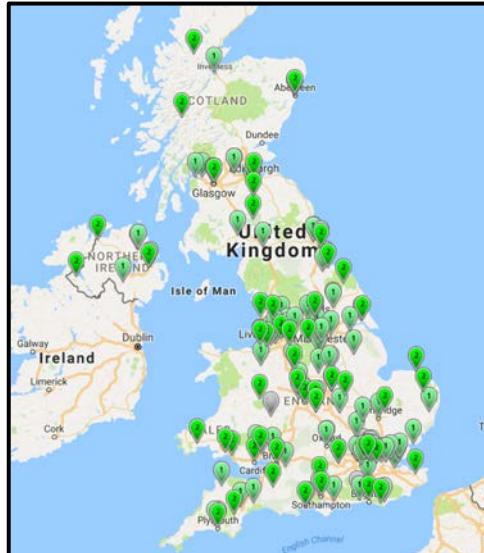
2018

UK Air Quality Monitoring

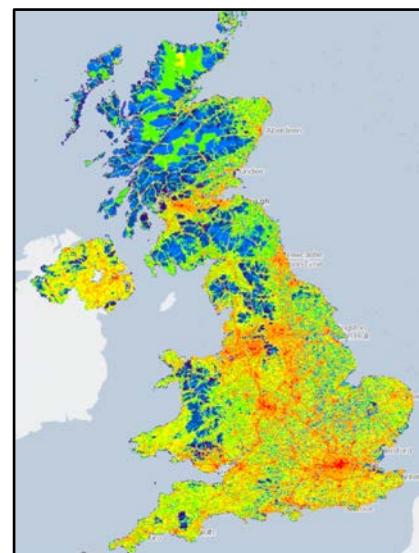
Current Approach:

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

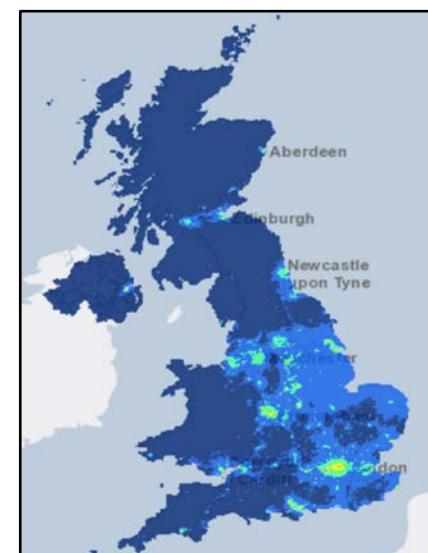
Network



Emissions



Models



UK Air Quality Monitoring

Shortcomings:

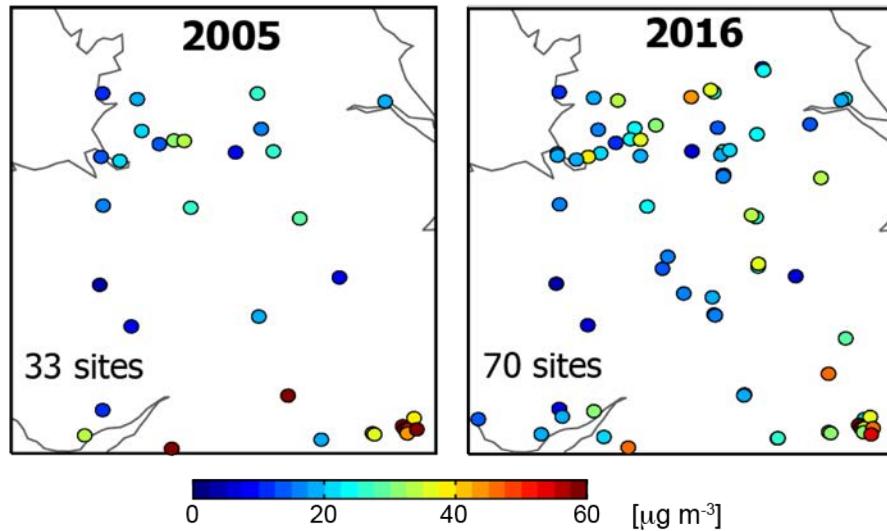
- **Austerity** (need to do more with less)
- **Costly** (£52k-£173k per monitor)
- **Laborious**
- **Large gaps** (space, time, frequency, pollutants)
- NAEI **inconsistent** from year-to-year
- **Limited validation** (large uncertainties)

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

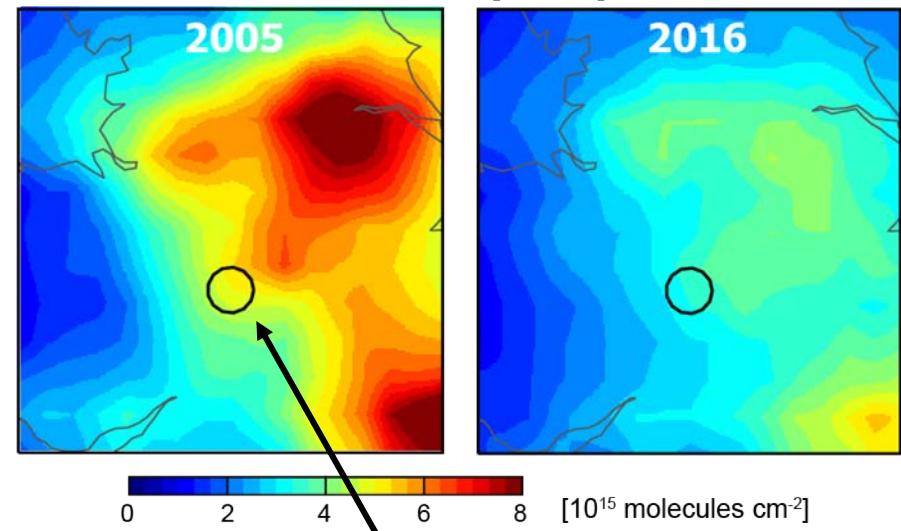
UK Air Quality Monitoring

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

DEFRA (surface) NO₂



Aura OMI (EO) NO₂



Excludes city council measurements

Birmingham:

3% per year decline in NO₂

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

Tool for Recording and Assessing the City Environment



TRACE

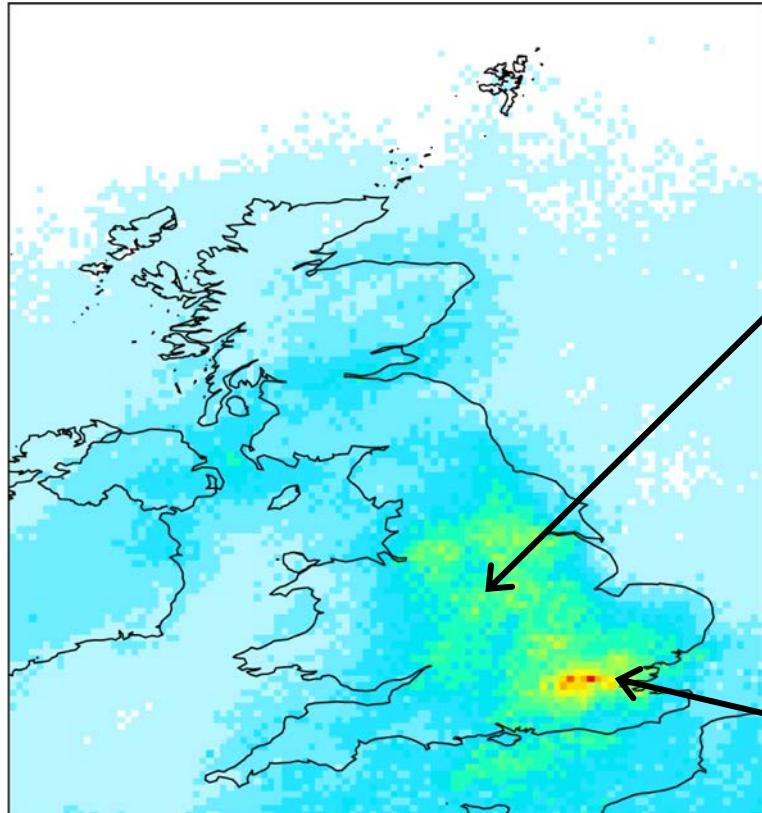
A data transformation and interpretation service to integrate Earth observations in air quality policy

Validation over UK Cities



Do satellites reproduce temporal variability of surface air pollution?

UK TROPMI NO₂

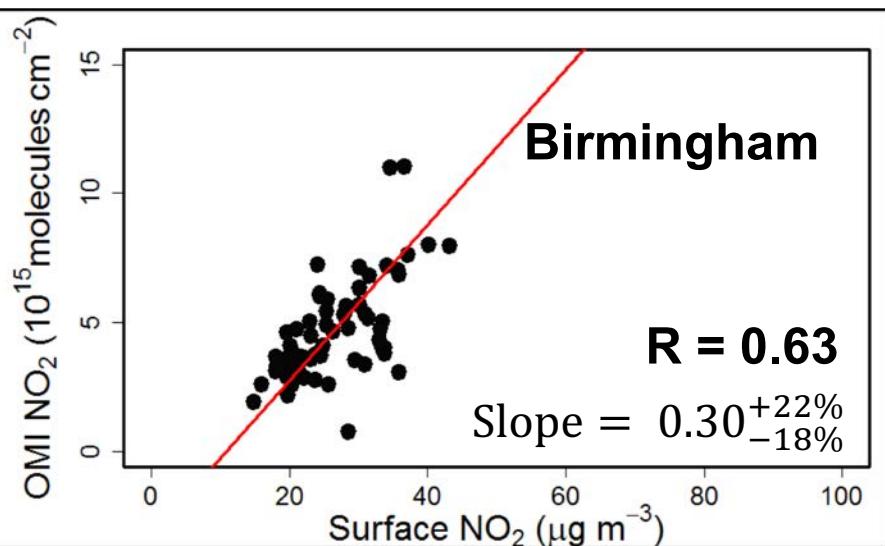


Validation over UK Cities

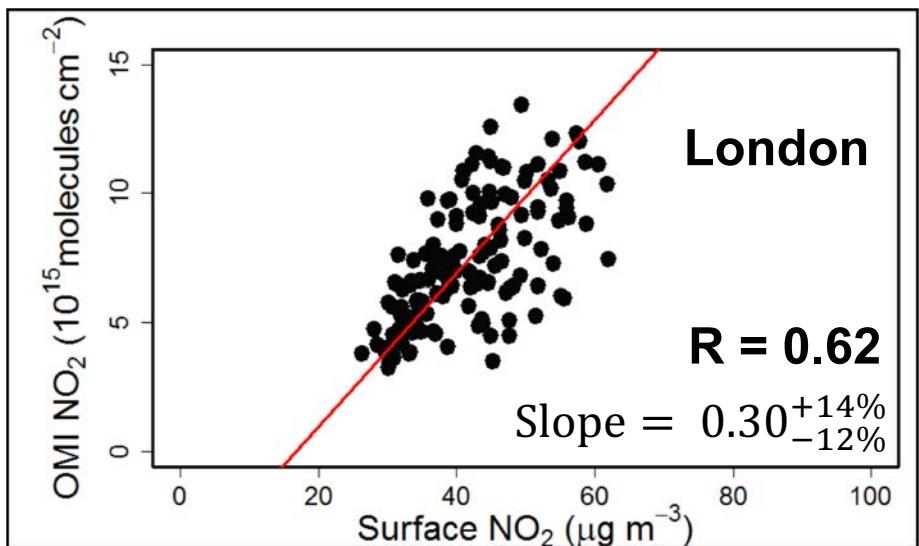


Demonstrate validity of satellite observations

Validation of Ozone Monitoring Instrument (OMI) NO₂ with surface measurements



March 2011 – September 2016



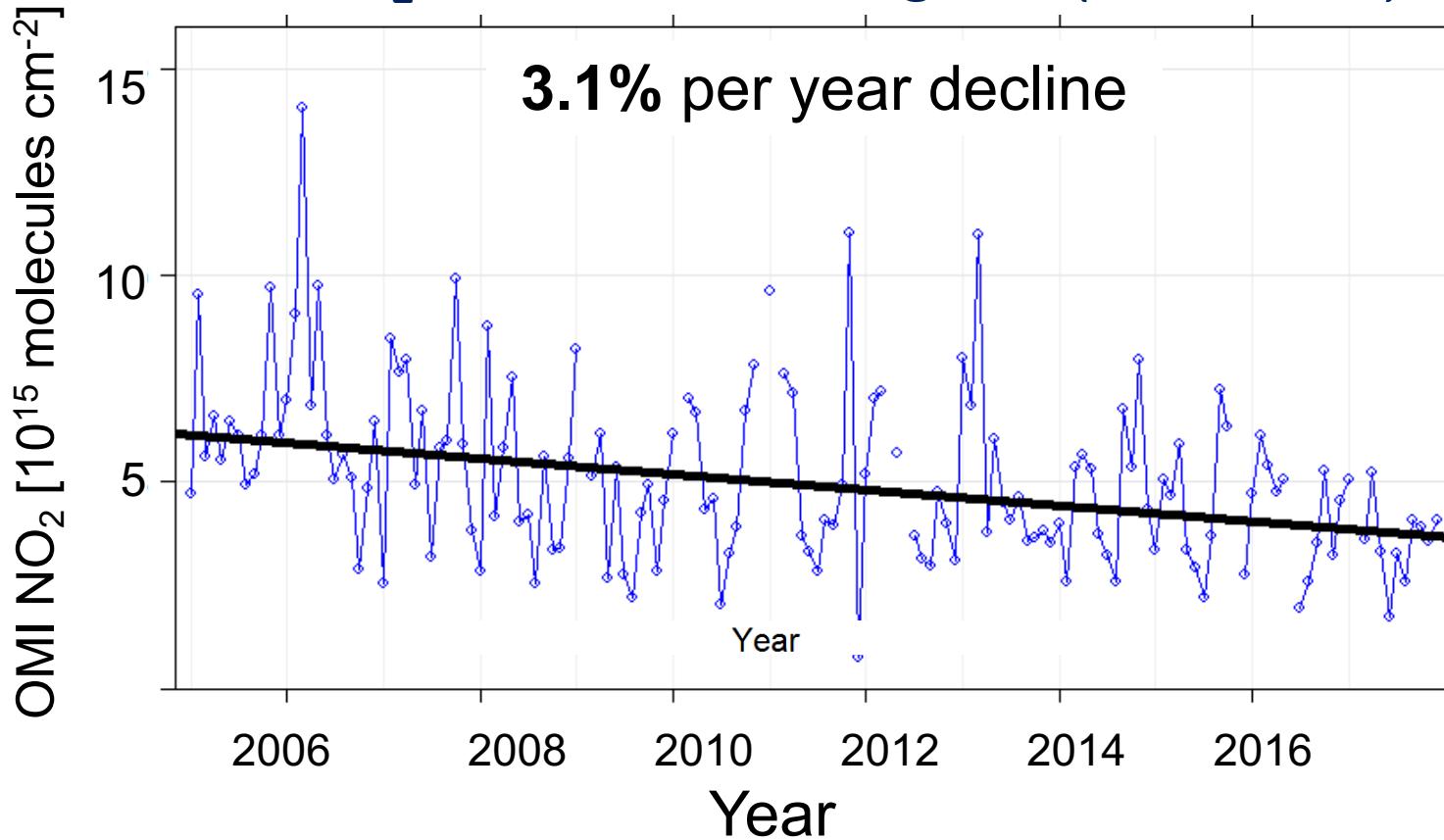
January 2005 – April 2018

Supported use of satellite observations to estimate long-term trends

NO_2 trends in UK Cities



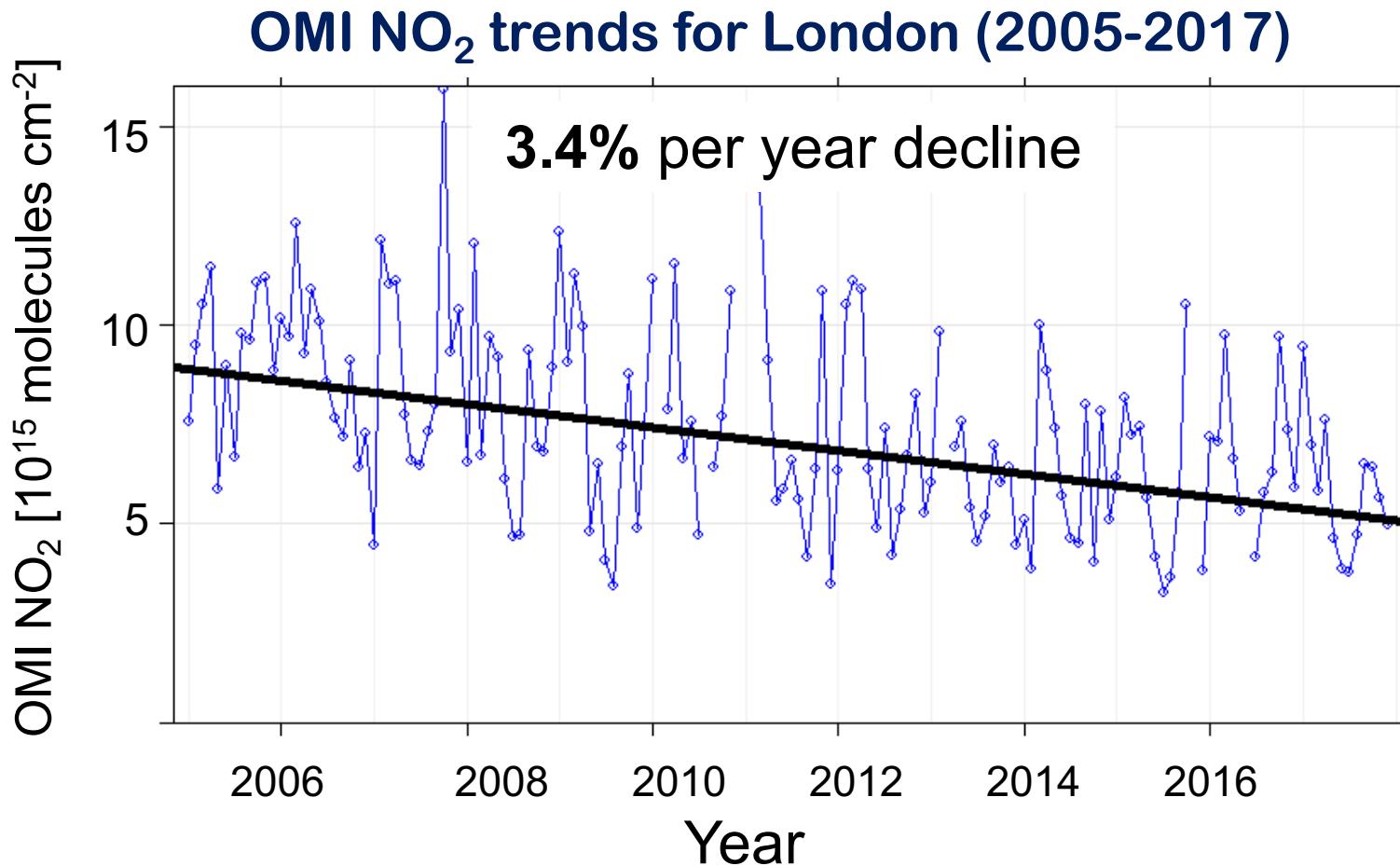
OMI NO_2 trends for Birmingham (2005-2017)



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

Not feasible to infer a trend with the surface network

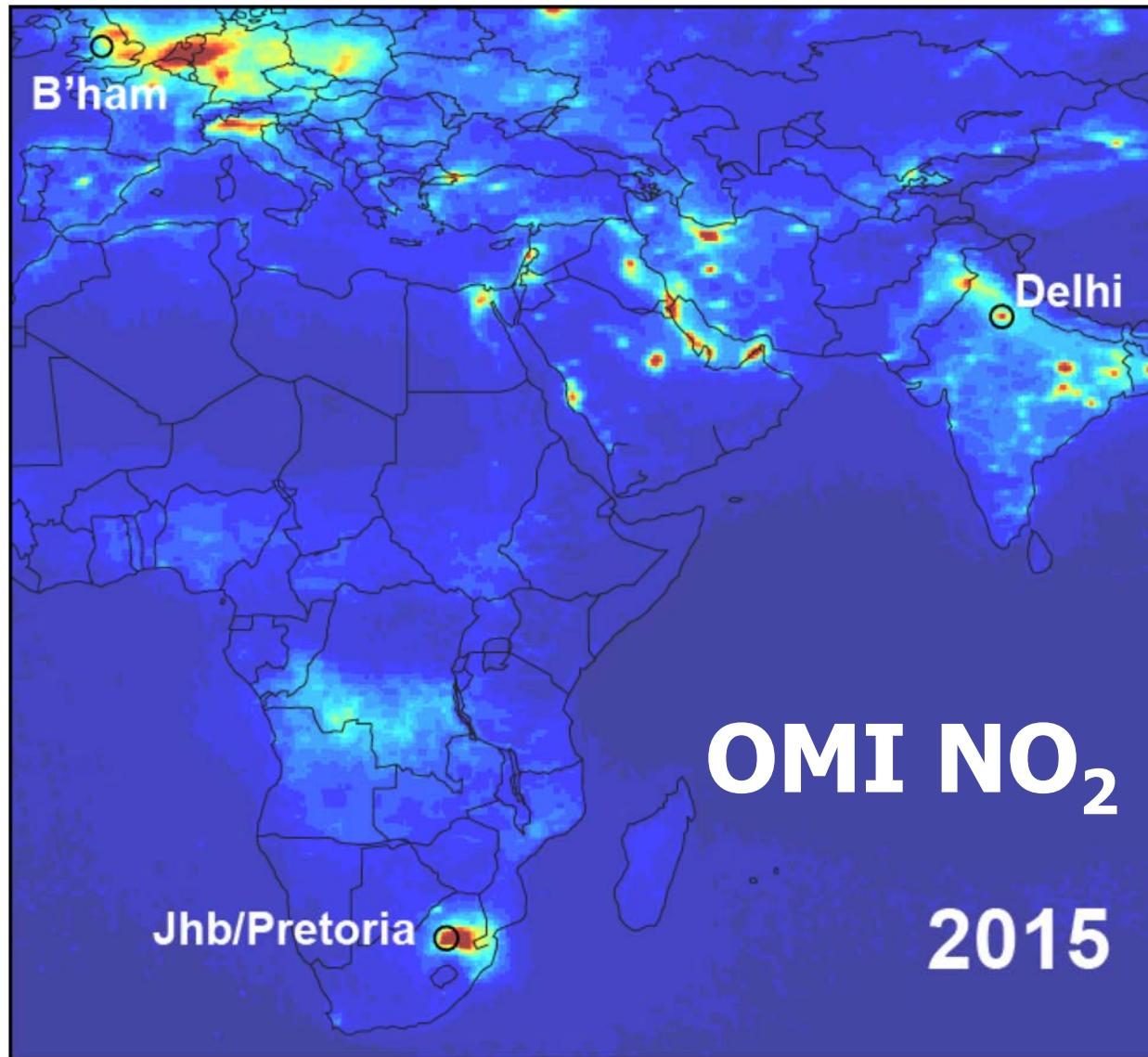
NO_2 trends in UK Cities



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

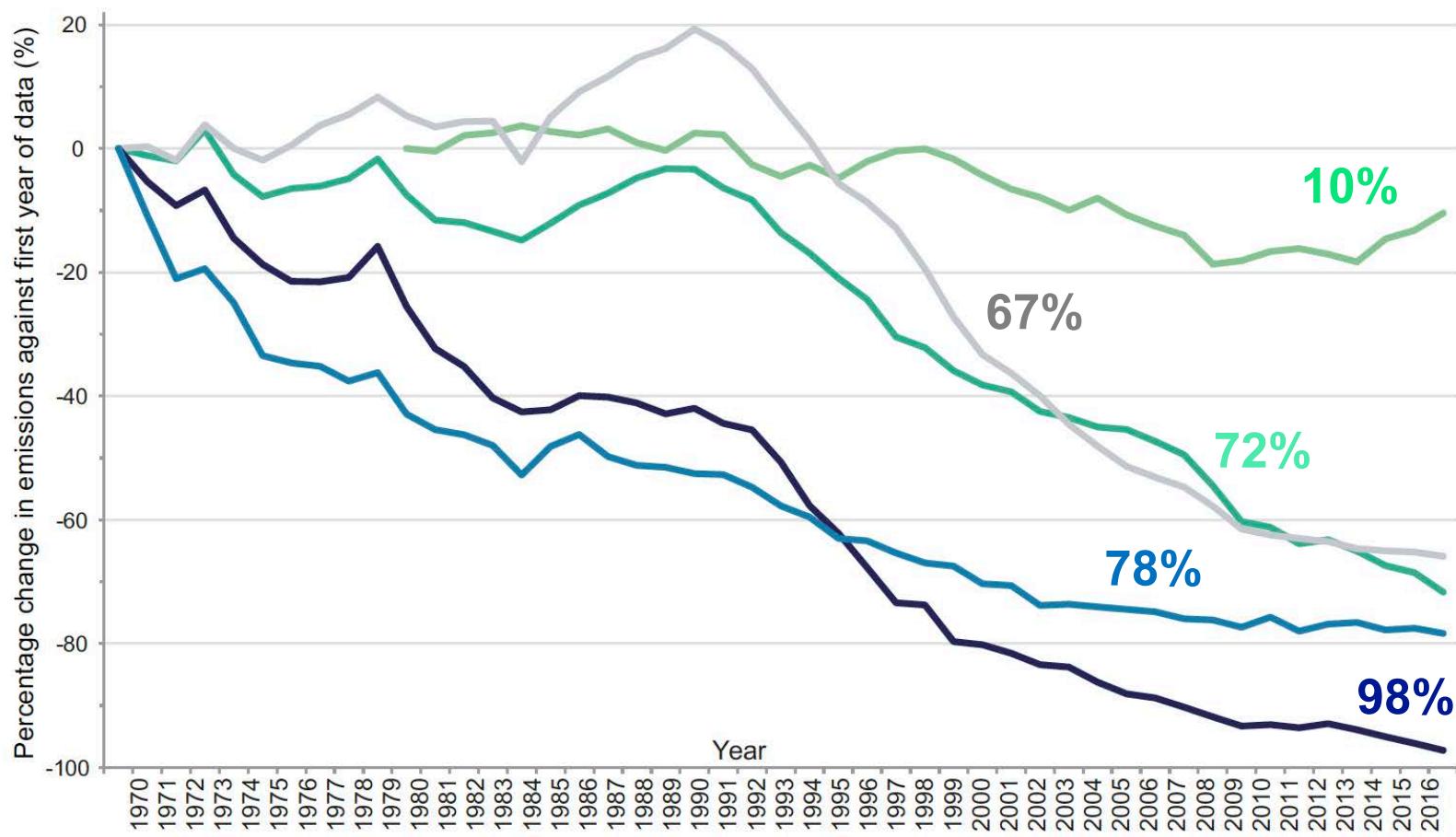
Trend from the **surface network** is only **-1.8% per year**
(almost half that from the satellite record)

Validate and Estimate Trends in India and South Africa



NH₃ Increasingly Important in the UK

Change in emissions of air pollutants since 1970 (since 1980 for ammonia)³



■ Ammonia

■ NO_x

■ NMVOCs

■ SO₂

■ PM_{2.5}

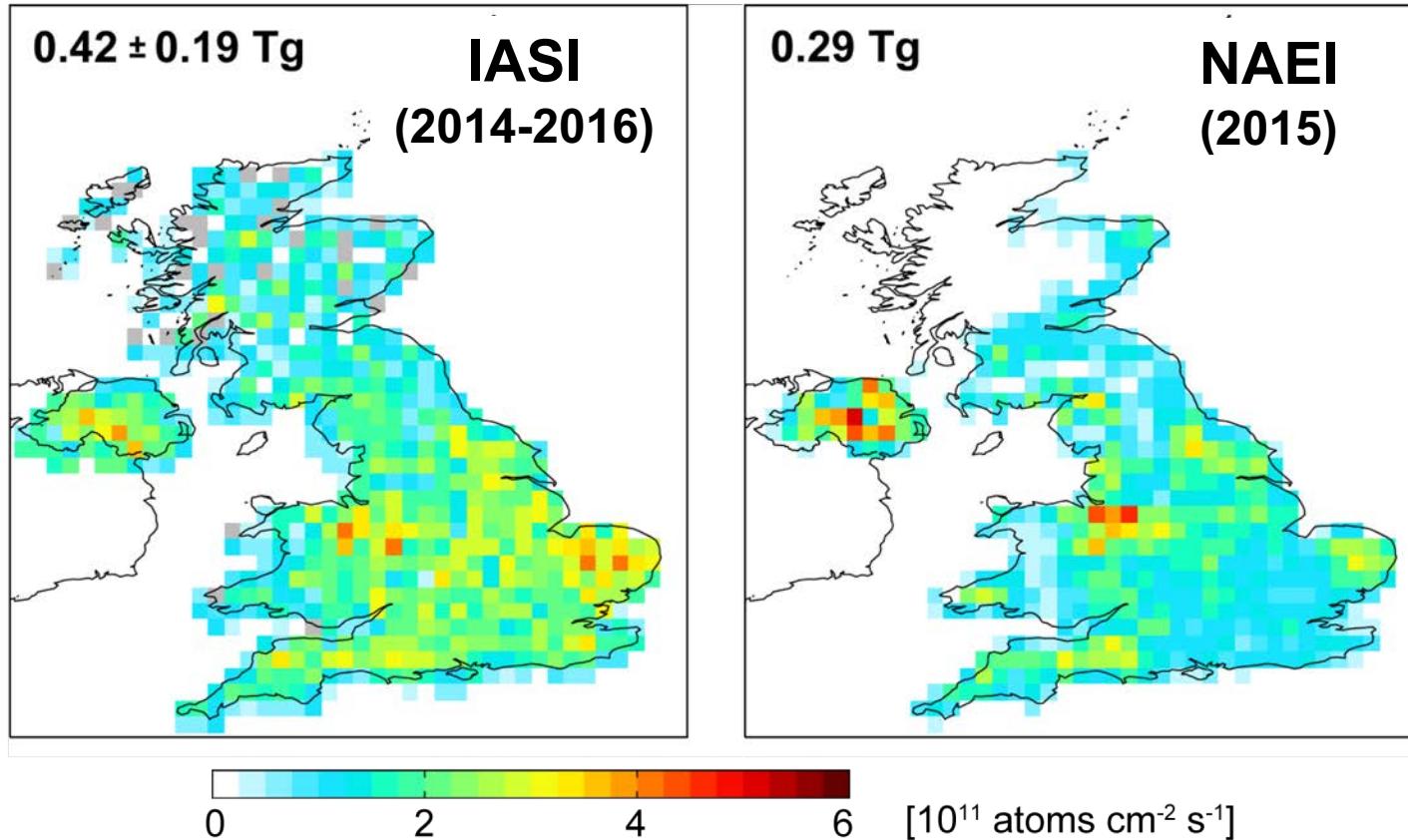
[DEFRA Clean Air Strategy, 2018]

NH₃ 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

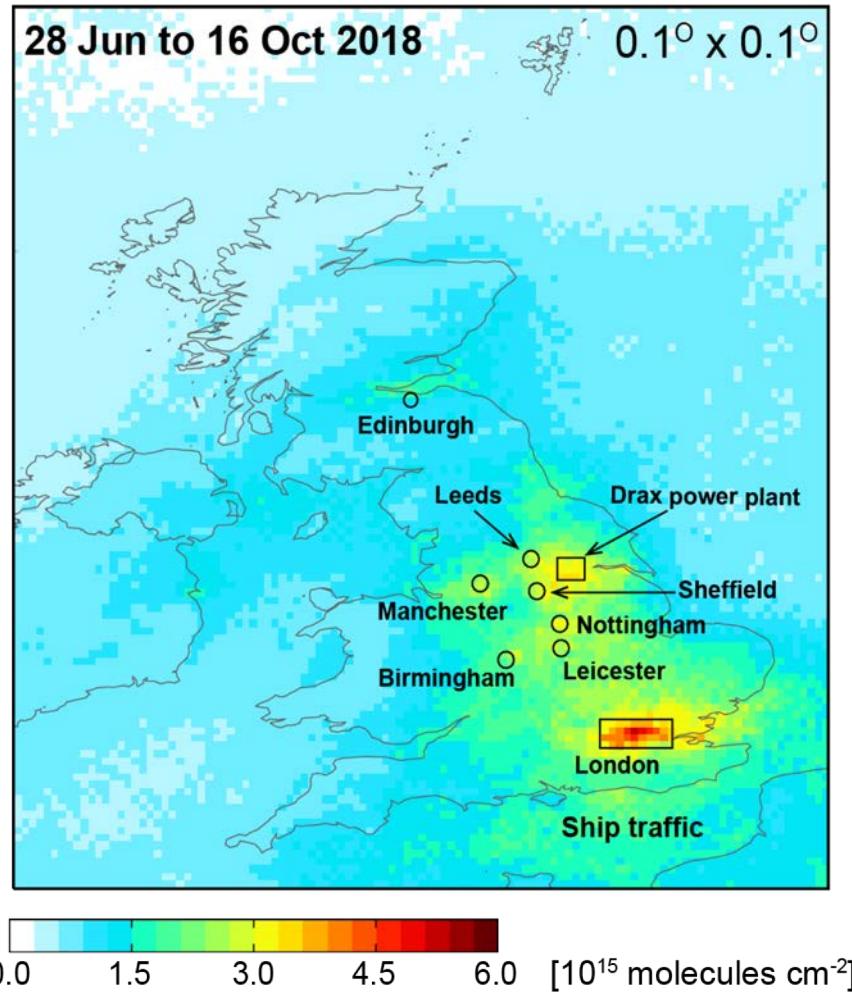


Overpass	13h30 LT	13h30 LT
Compounds	NO_2 , O_3 , HCHO, SO_2 CHOCHO, AI, AOD	Same as OMI + CH_4 and CO
Resolution	13 km × 24 km	7 km × 3.5 km

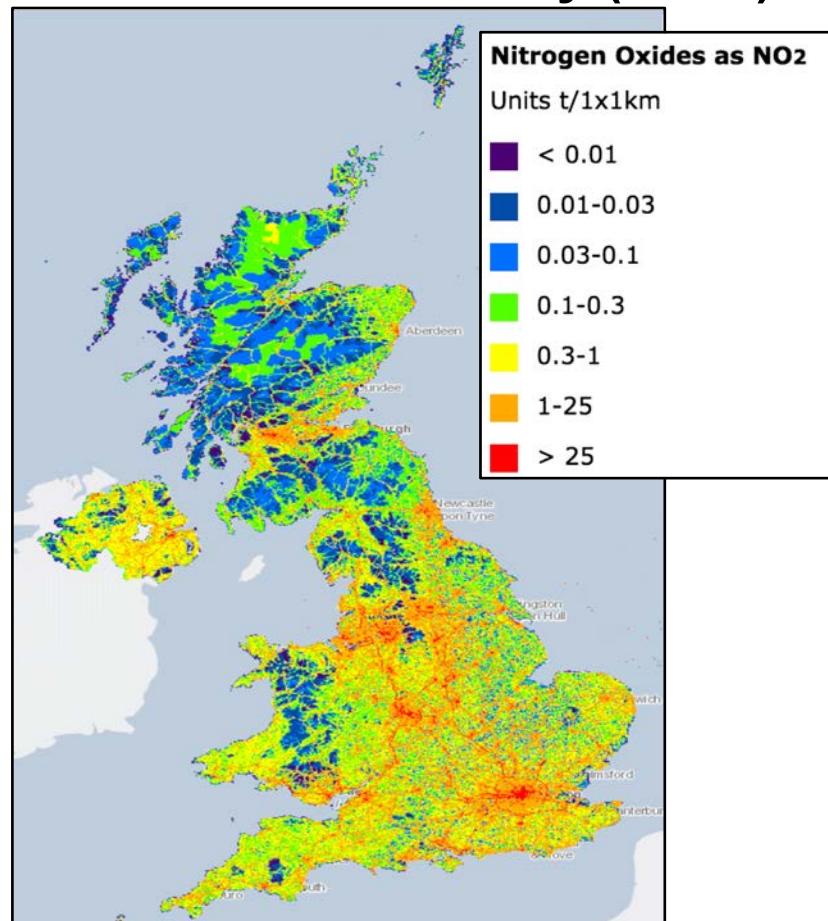
Constrain spatial variability of pollutants and evaluate high-resolution air quality monitoring tools (models and inventory)

Exploit high spatial resolution of TROPOMI

TROPOMI NO₂ over the UK



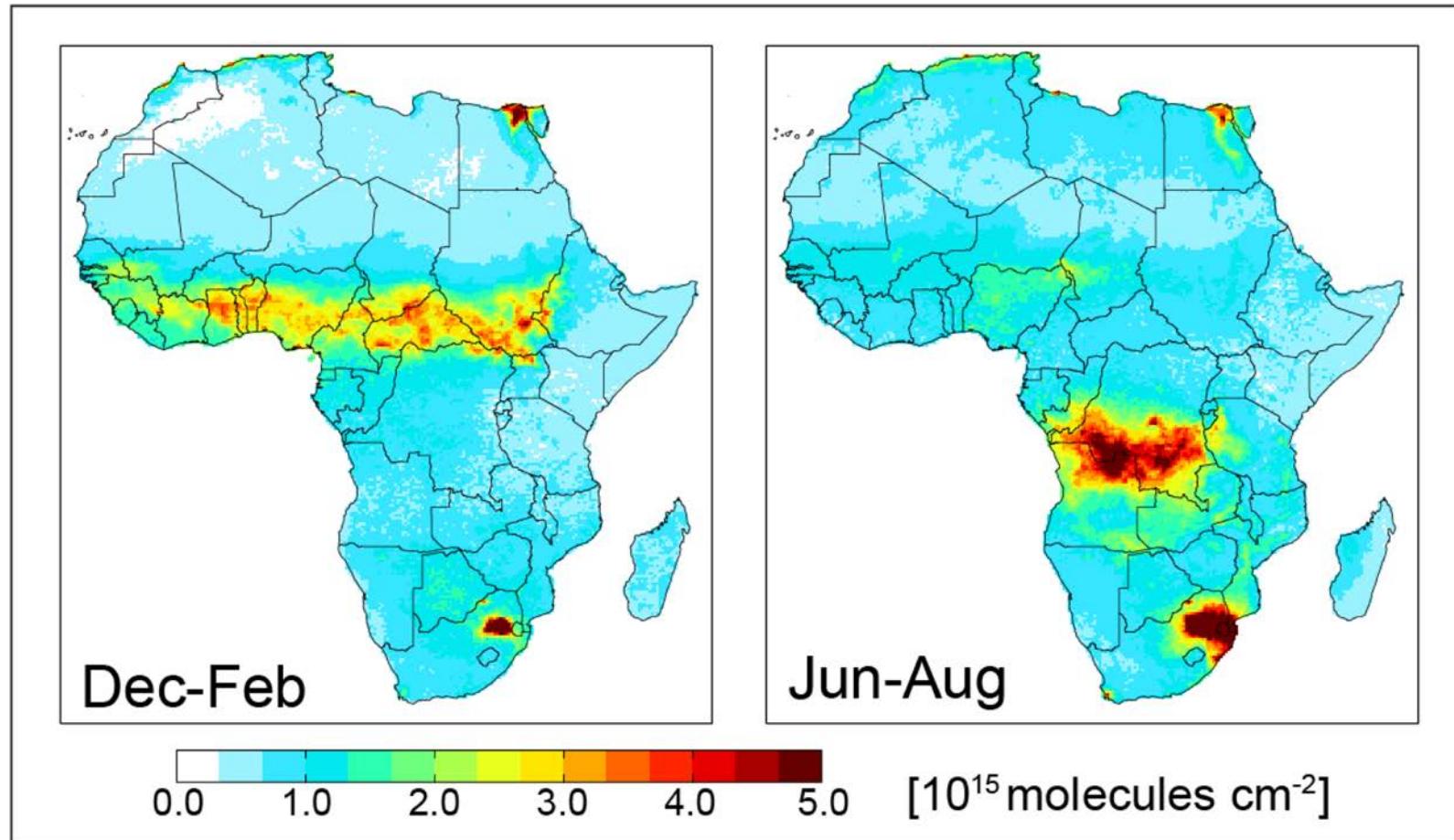
National Atmospheric Emission Inventory (NAEI)



Evaluate high-resolution emission inventory and air quality models

More challenging to do in Africa

Seasonal mean tropospheric NO₂ column densities for 2006-2007

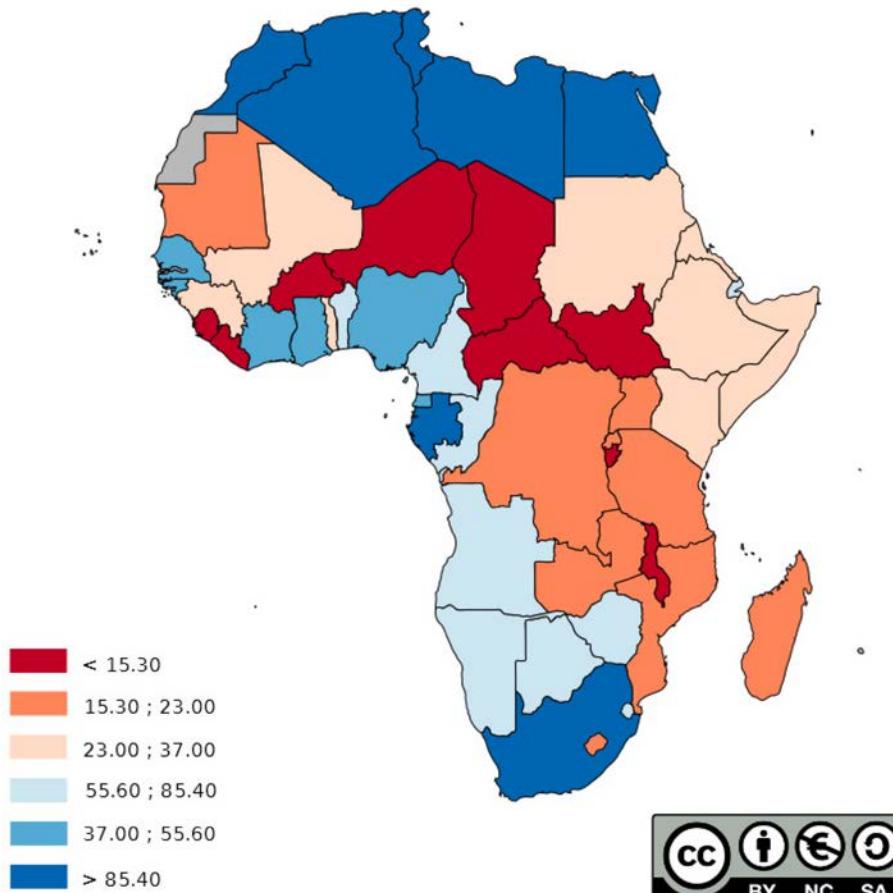


[Marais and Chance, 2015]

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

Limited Access to On-Grid Electricity

Access to Electricity (% of population)



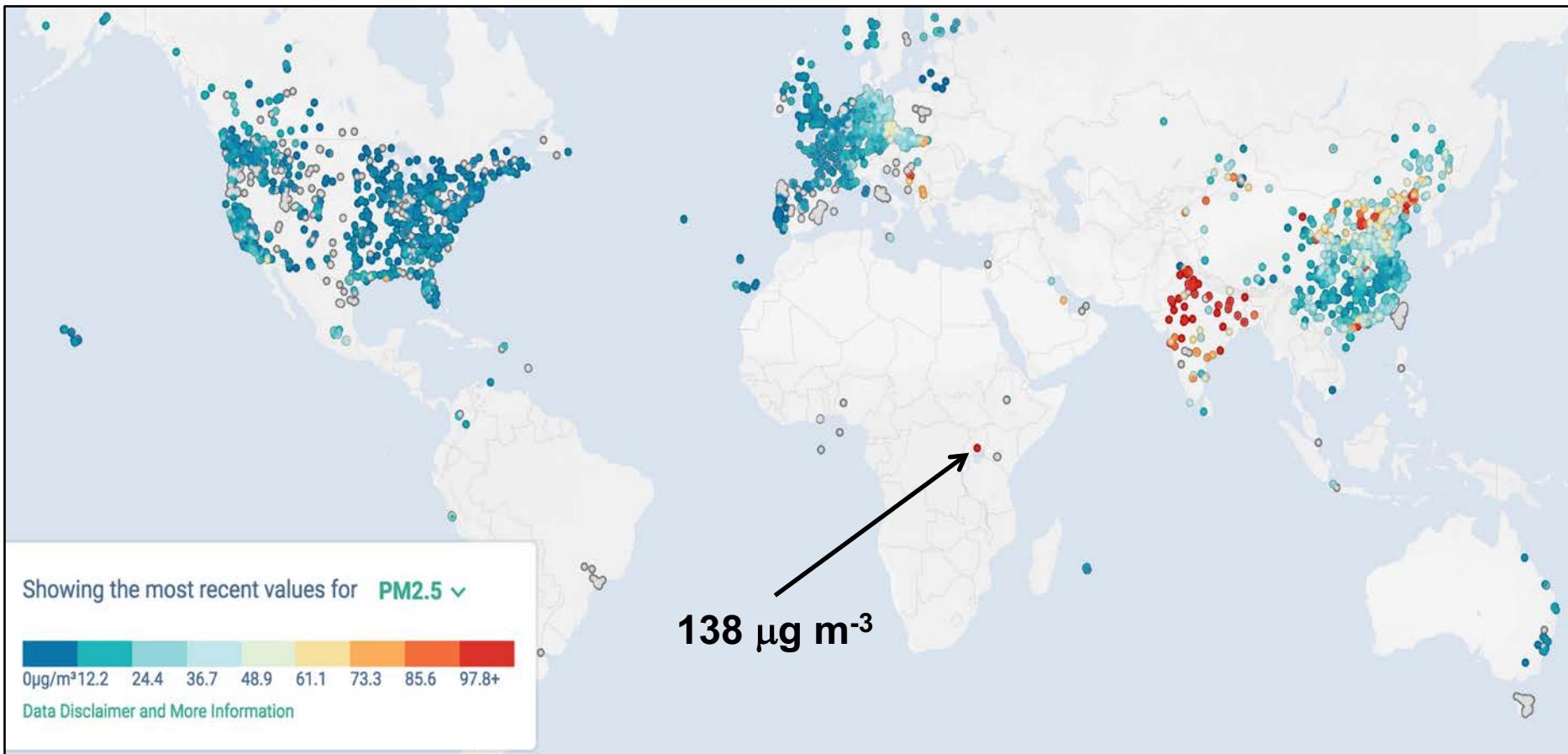
Source : The World Bank - 2012

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

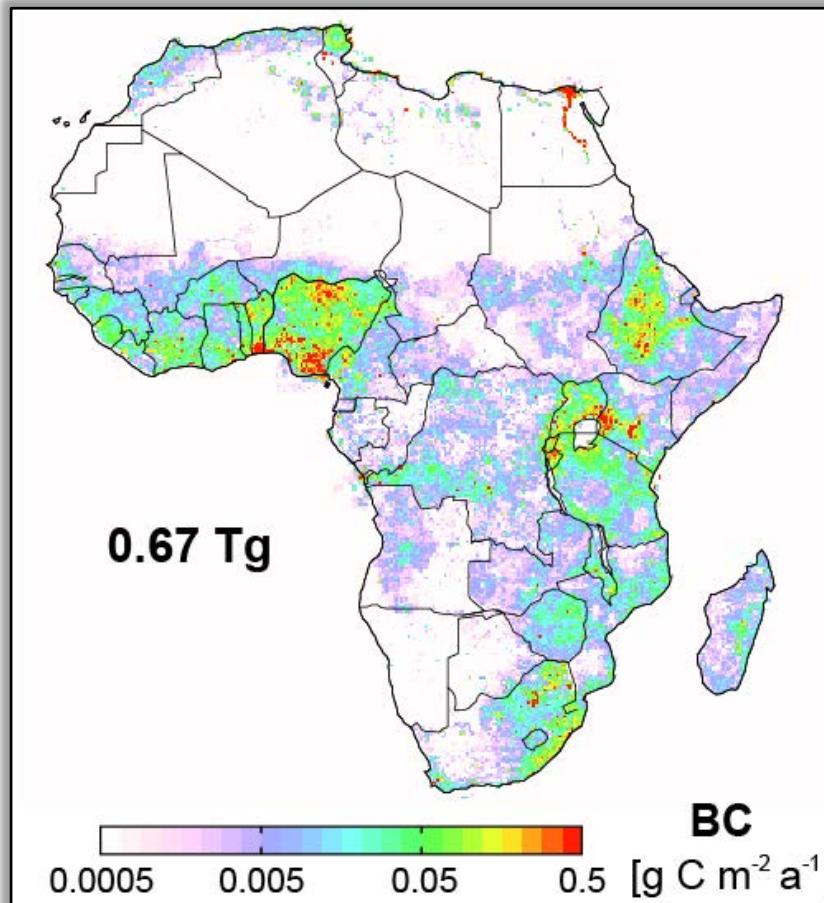
Severely Limited Surface Measurements



[OpenAQ, Accessed 7 November 2018]

Diffuse and Inefficient Combustion Emissions (DICE-Africa)

Black Carbon



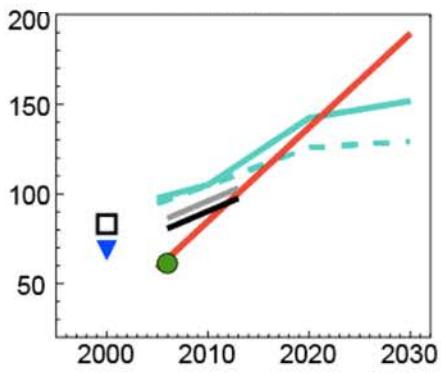
[Marais and Wiedinmyer, 2016]



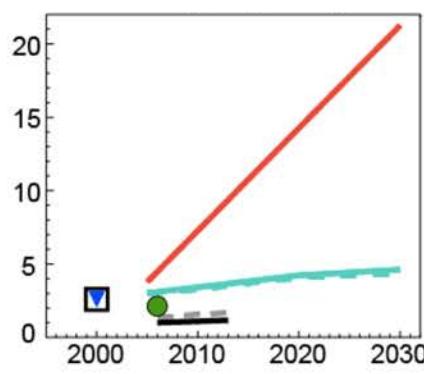
DICE and open fire emissions similar for many pollutants

Emissions Trends and Projections for Africa

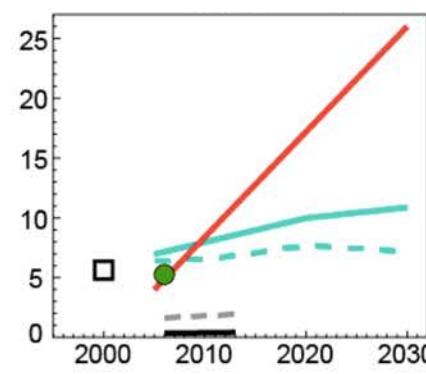
CO (Tg)



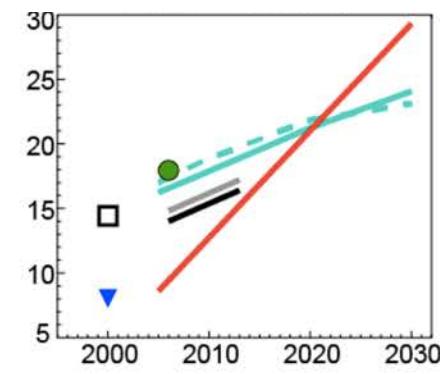
NO_x (Tg NO)



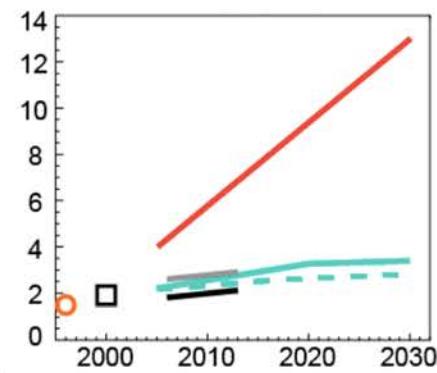
SO₂ (Tg)



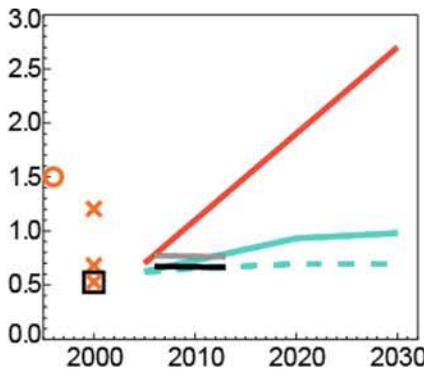
NMVOCs (Tg)



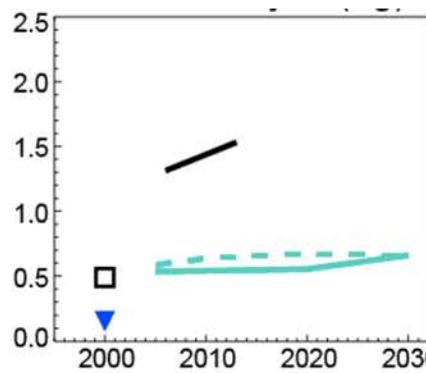
OC (Tg C)



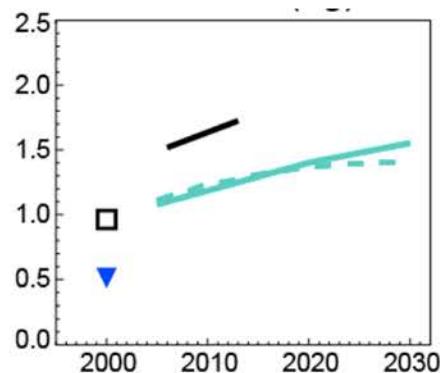
BC (Tg C)



HCHO (Tg)



Benzene (Tg)



— DICE-Africa

— RCP 4.5

○ Bond et al. (2004)

--- This study + hard coal

— RCP 8.5

✗ Bond et al. (2013)

— This study + trash burning

● EDGAR v4.2

□ ACCMIP

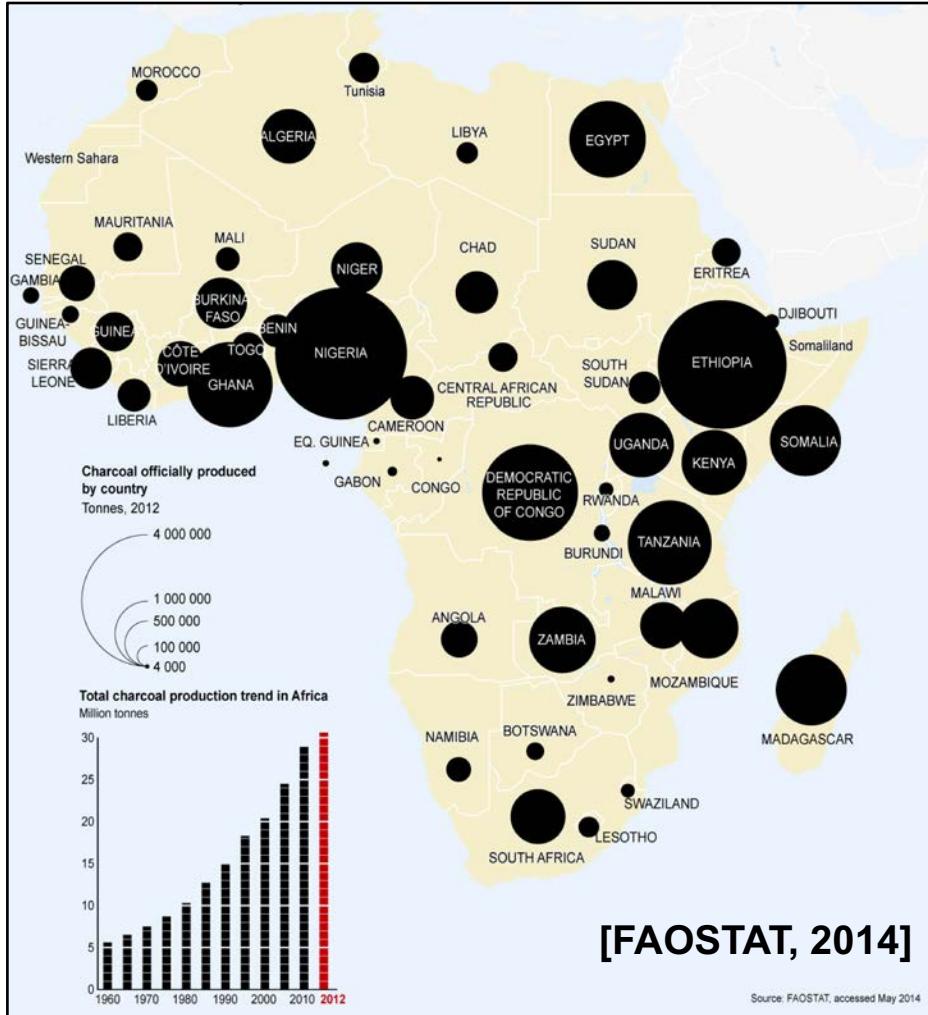
— Liousse et al. (2014)

▼ RETRO v2

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

A Focus on Charcoal Production

Charcoal Production in Africa



Major export in Somalia fueling civil unrest there

6-9% per year increase in production

Improved representation of charcoal emissions



**Production
(RURAL)**

Transport



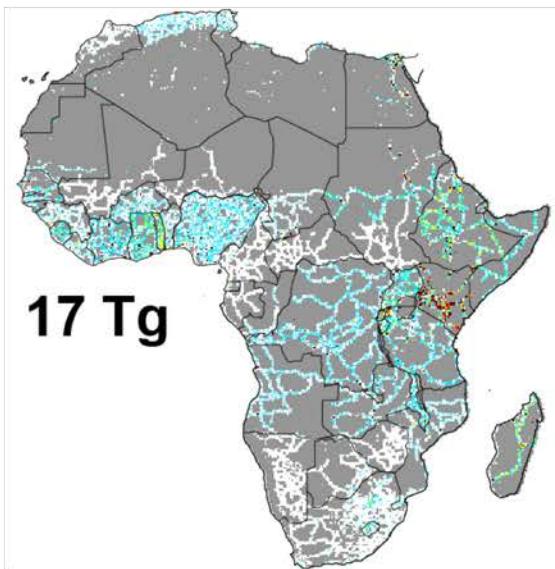
**Use
(URBAN)**



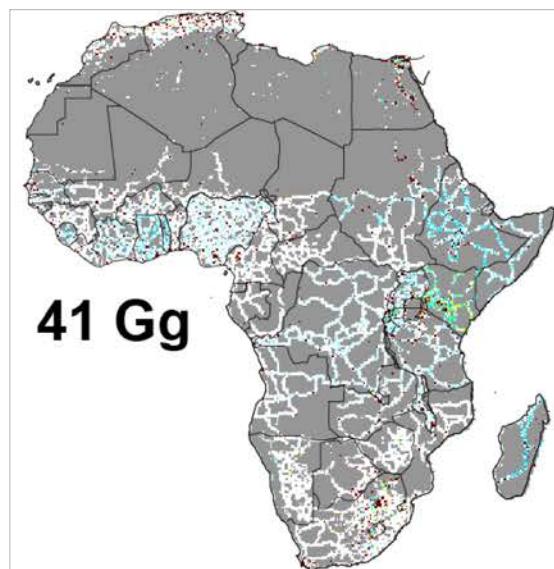
Improved representation of charcoal emissions

Pollutant emissions from charcoal production, use and transport

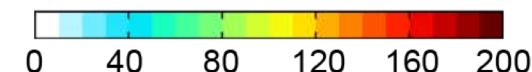
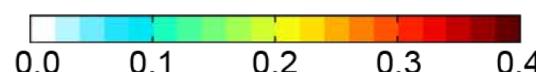
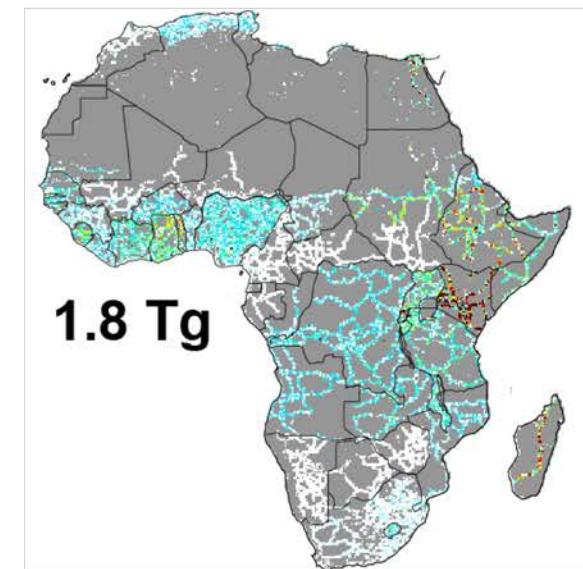
CO [10³ tonnes]



BC [tonnes]



CH₄ [tonnes]



Annual biomass burning emissions in Africa:

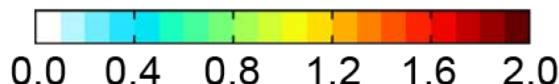
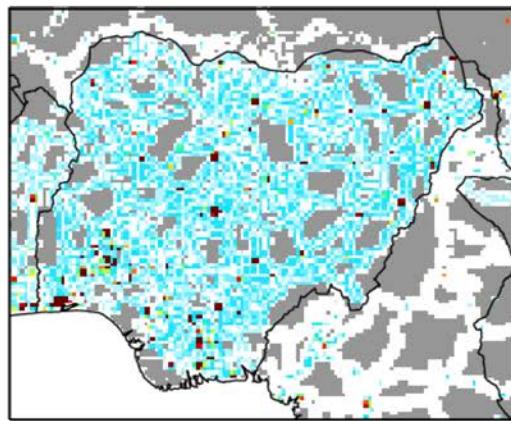
440 Tg CO; 2.6 Tg BC; 15 Tg CH₄ [Y. Shi et al., 2015]

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

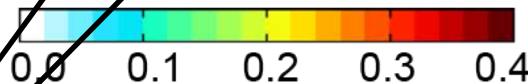
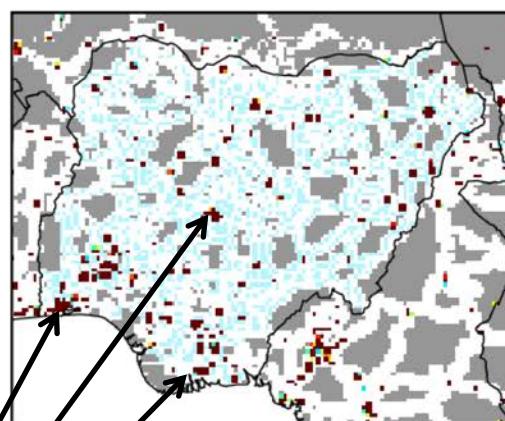
Improved representation of charcoal emissions

Zoom in to Nigeria (largest charcoal producer in Africa)

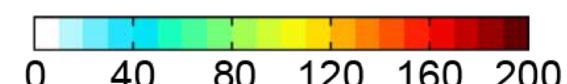
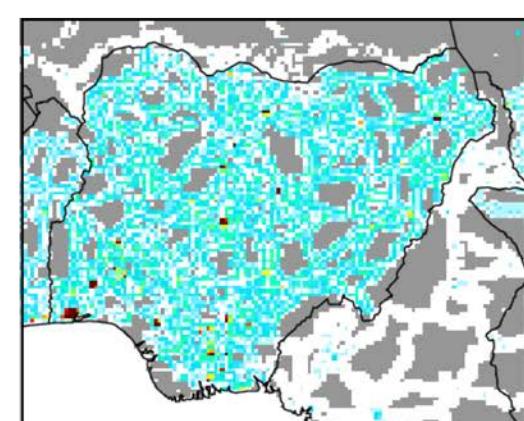
CO [10³ tonnes]



BC [tonnes]



CH₄ [tonnes]



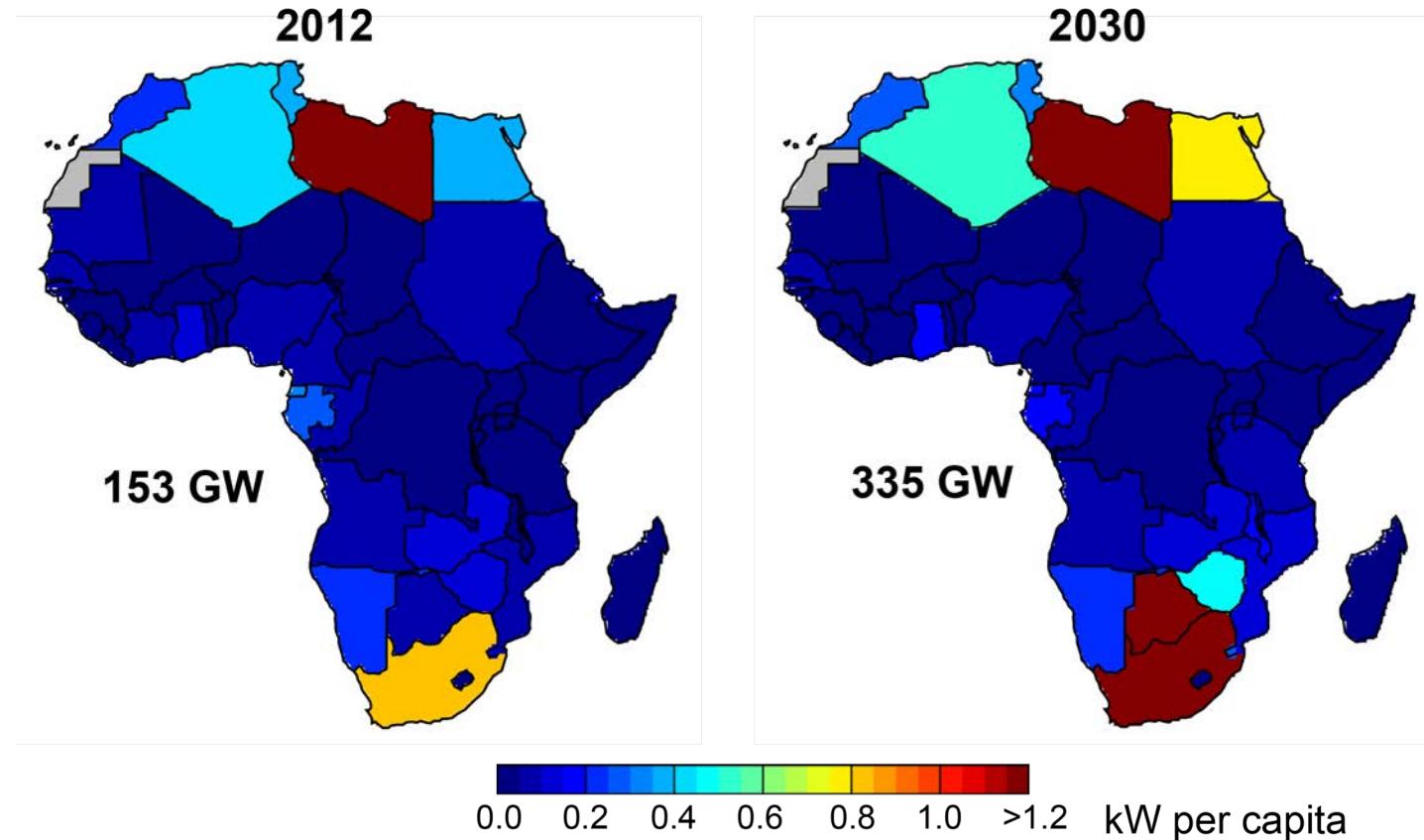
Hot spots in urban centres

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

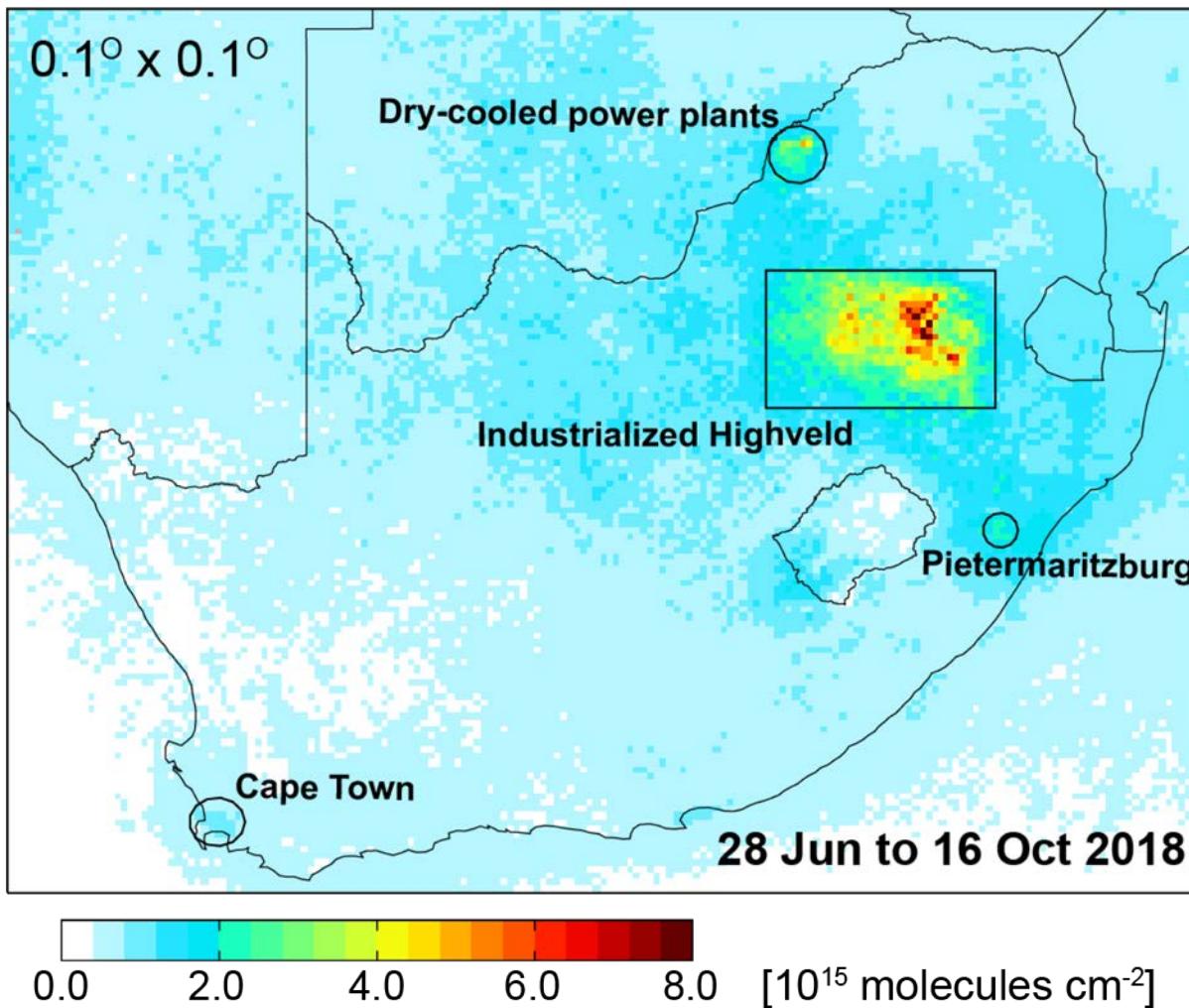


2012-2030 installed capacity increase: 120%

2012-2030 population increase: 54%.

Even Challenging with TROPOMI

TROPOMI NO₂ over South Africa



NO₂ enhancements from dry-cooled power plants in South Africa

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

SO_2

NO_x (as NO)

Primary particles

2012

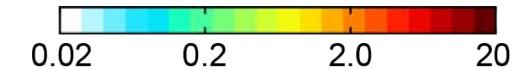
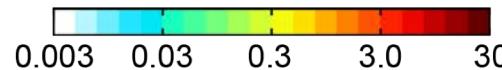
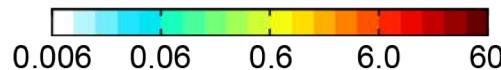


2030

5.4 Tg

2.7 Tg

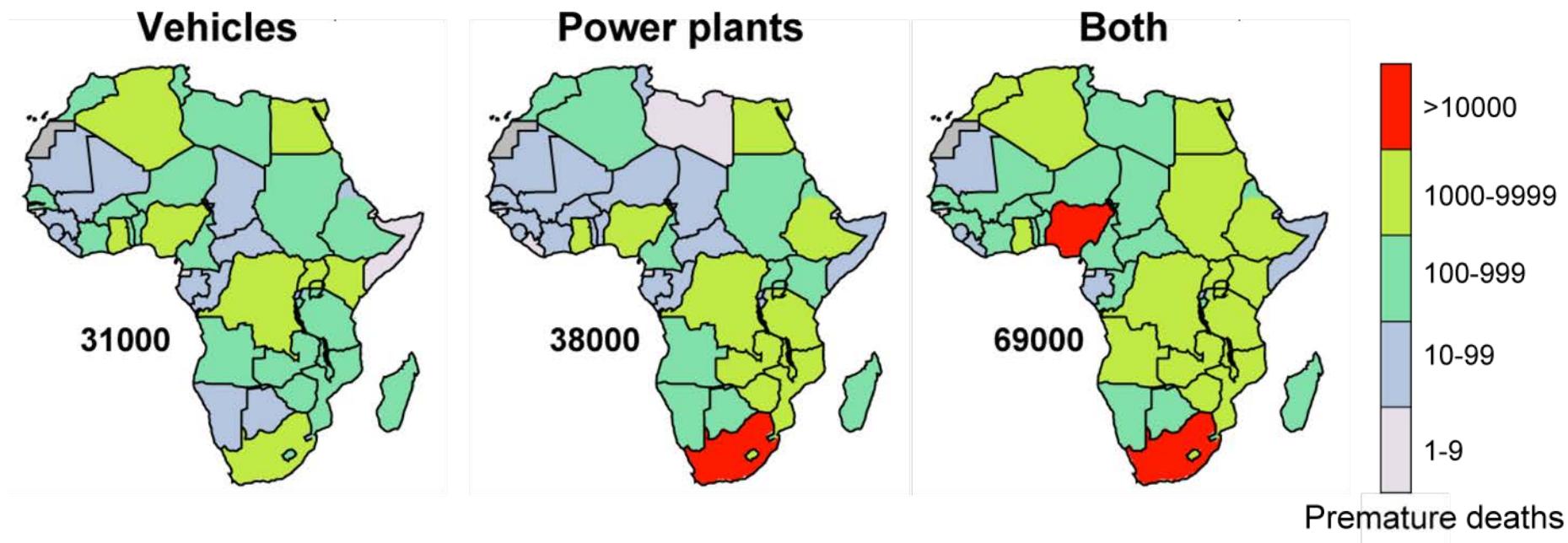
1.9 Tg



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



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Engineering and Physical Sciences
Research Council

