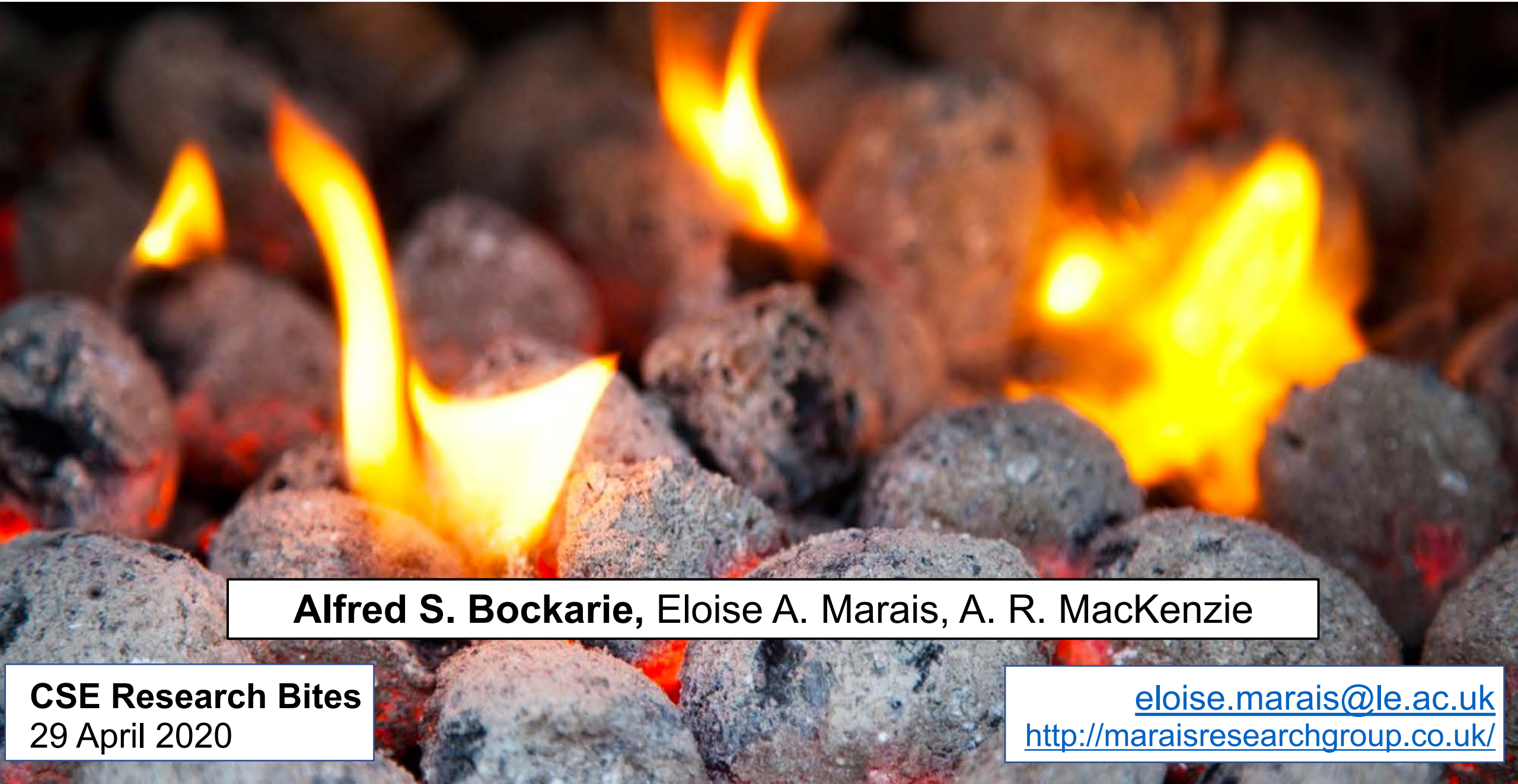
Air Quality and Climate Impact of the Charcoal Industry in Africa



Alfred S. Bockarie, Eloise A. Marais, A. R. MacKenzie

CSE Research Bites
29 April 2020

eloise.marais@le.ac.uk
http://maraisresearchgroup.co.uk/

Multiplatform Approach to Solve Issues of Pressing Need

CHAMBER

GEOS Chem

3D ATMOSPHERIC CHEMISTRY MODEL

SATELLITES

IN SITU

My group uses and develops state-of-science observations and tools to inform policy.

Tracking Success and Absence of Air Quality Policies in Cities

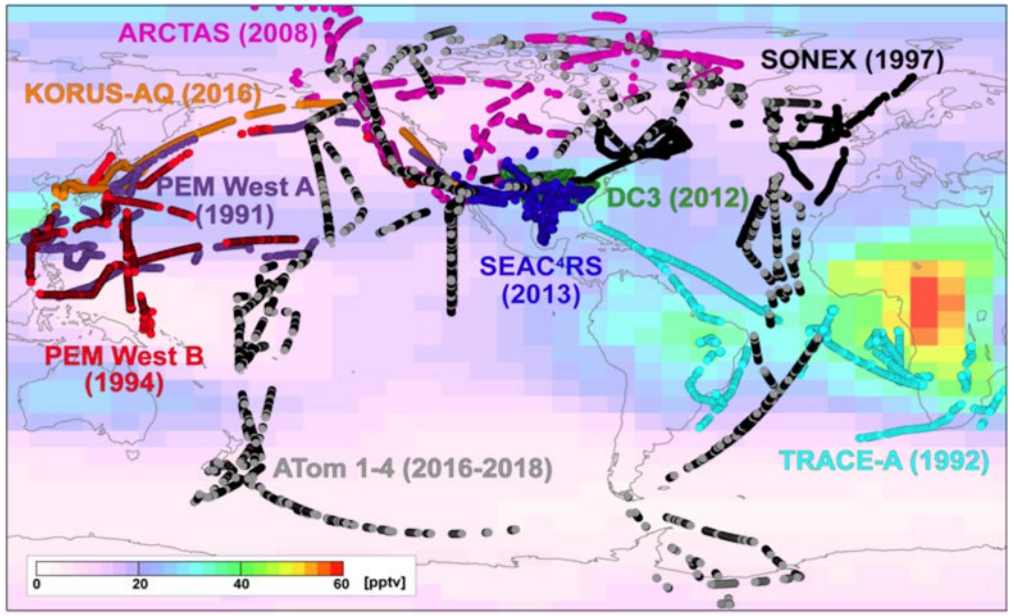
Air pollutant	London	Birmingham	Delhi	Kanpur
NO_2 (2005-2018)	↓	↓	↑	↑
NH_3 (2008-2018)	↑	↑	↑	↑
NMVOCs (2005-2018)	↑	↓	↑	↑
$PM_{2.5}$ (2005-2018)	↓	↓	↑	↑

Increase / Decrease

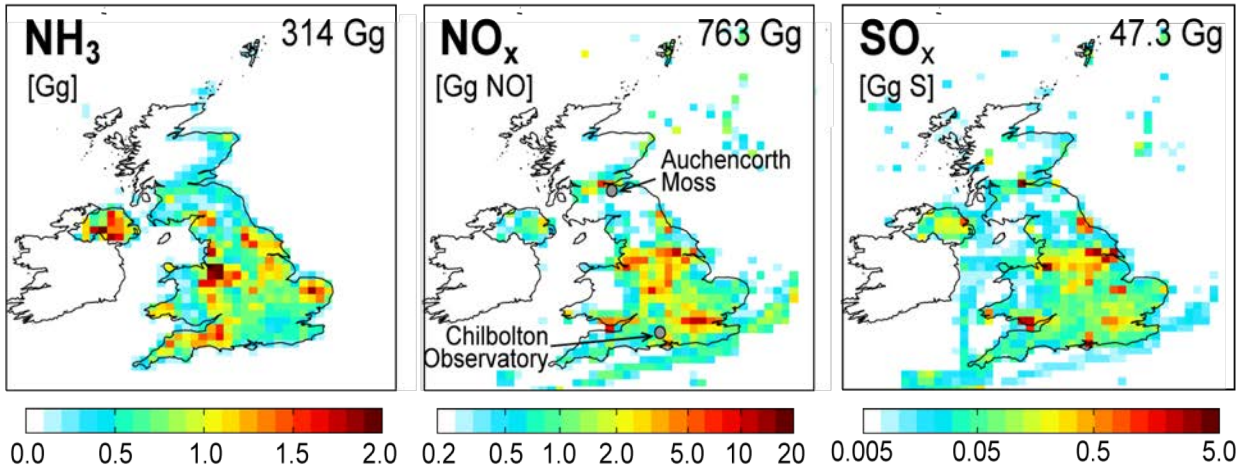
Significant? Yes / No

Trend (in % year^{-1}): 4, 2

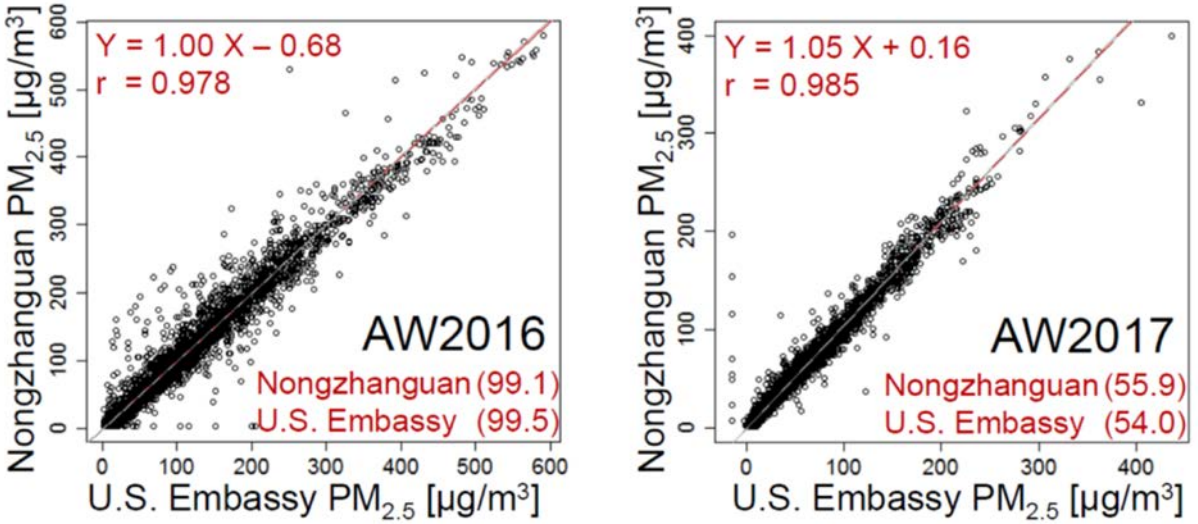
The Underappreciated Upper Troposphere



Assessing the UK Emission Inventory with Earth Observations



Assessing strict air quality policies in North China



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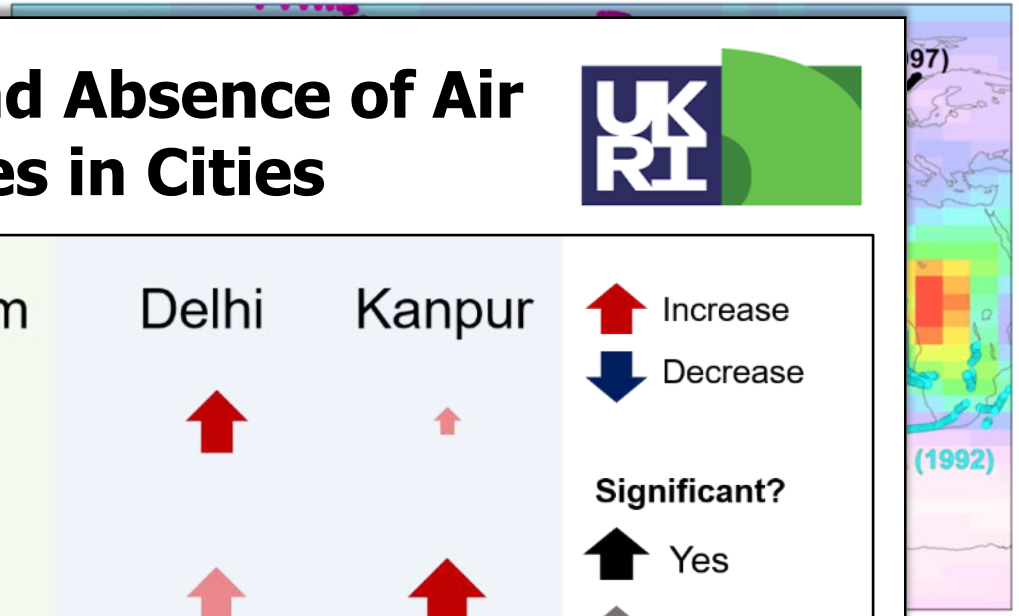
Increase / Decrease

Significant? Yes / No

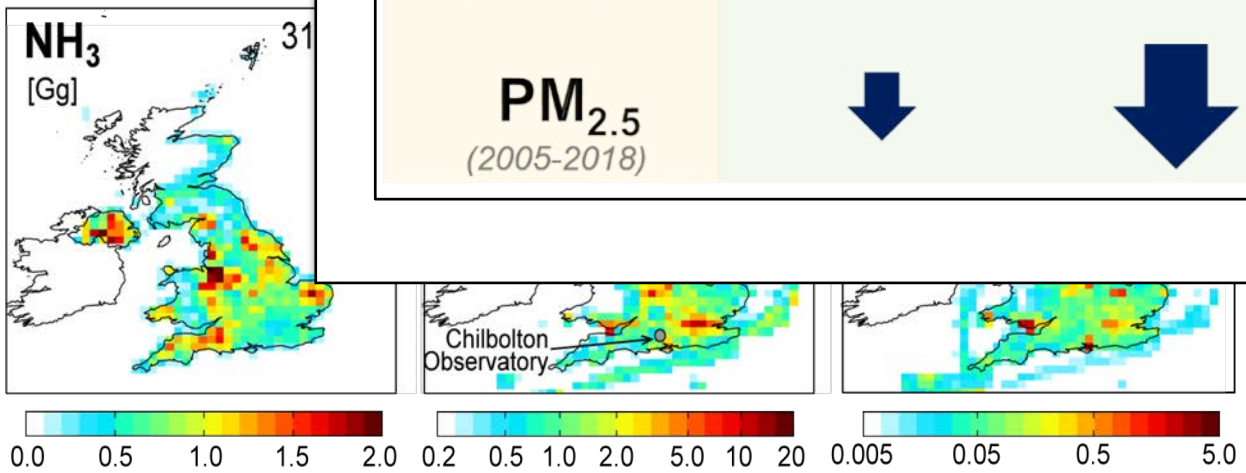
Trend (in % year^{-1}): 2 – 4

Vohra et al., submitted, 2020

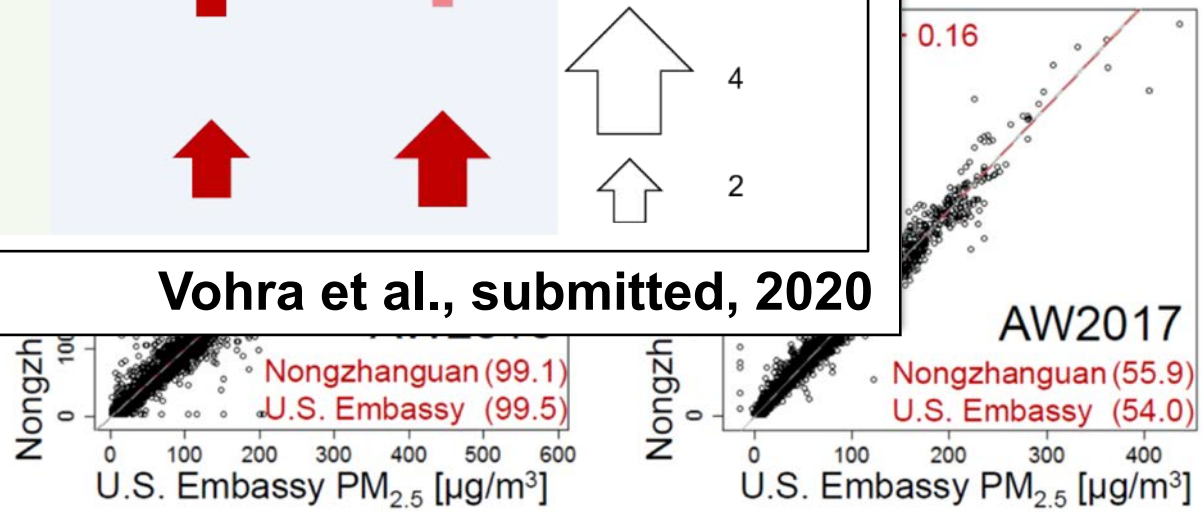
The Underappreciated Upper Troposphere



Assessing t… with …



… North China



Tracking Success and Absence of Air Quality Policies in Cities

Air pollutant	L
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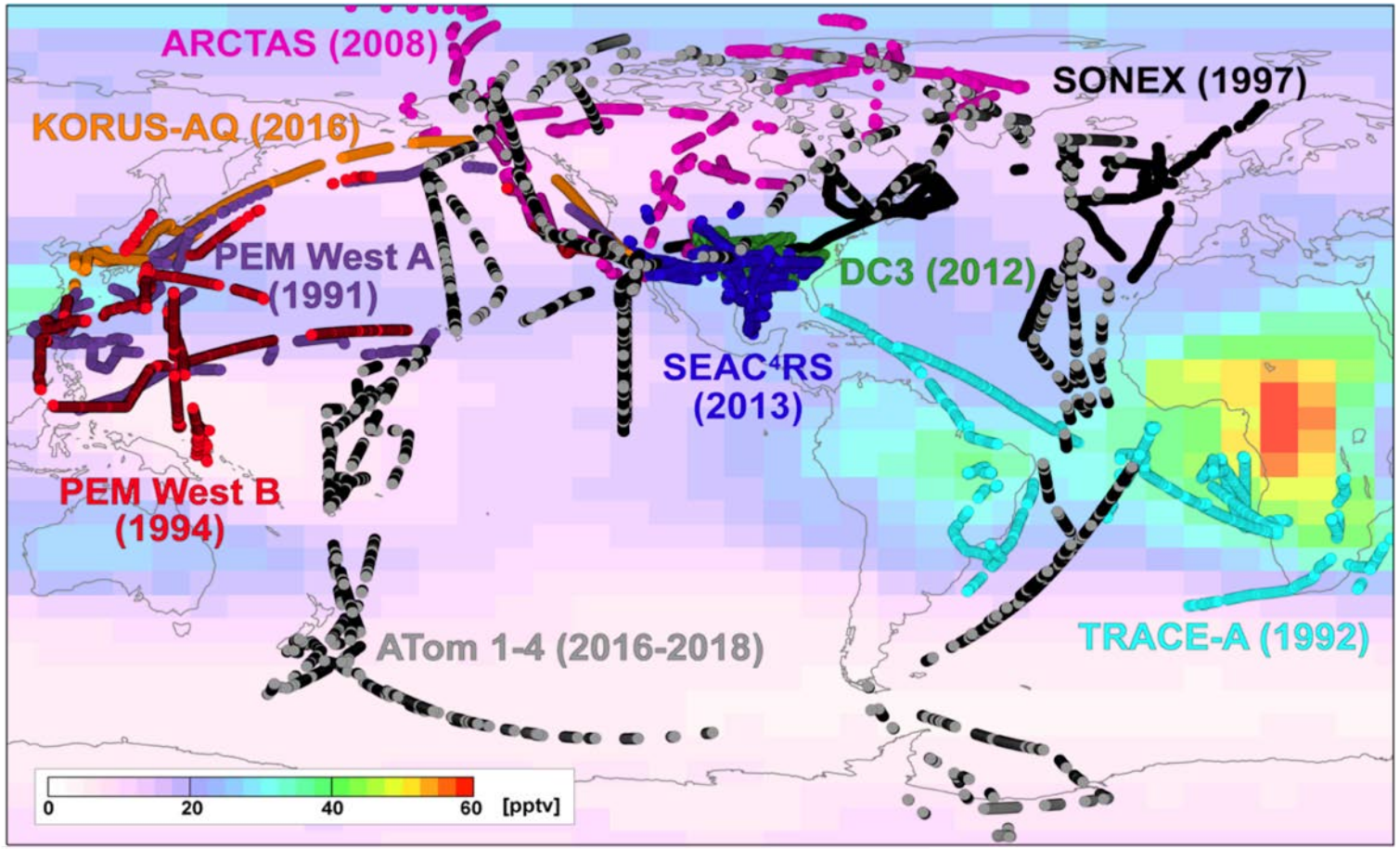
NH_3 (2008-2018)	
NMVOCs (2005-2018)	
$PM_{2.5}$ (2005-2018)	

The Underappreciated Upper Troposphere



Wei et al., in progress

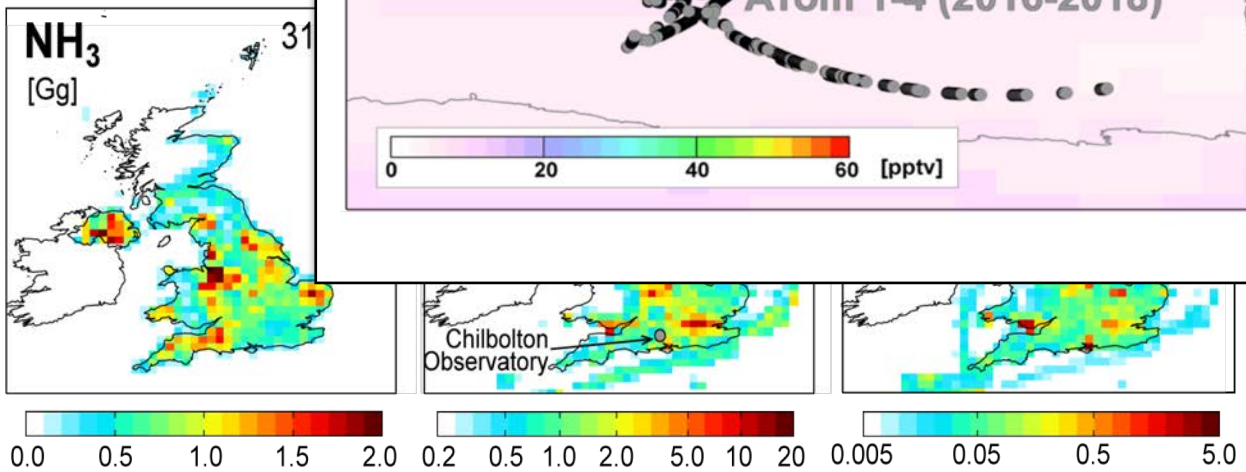
erc

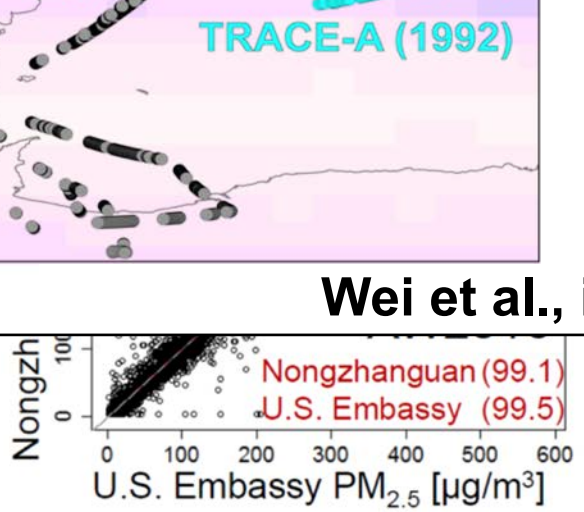
NASA

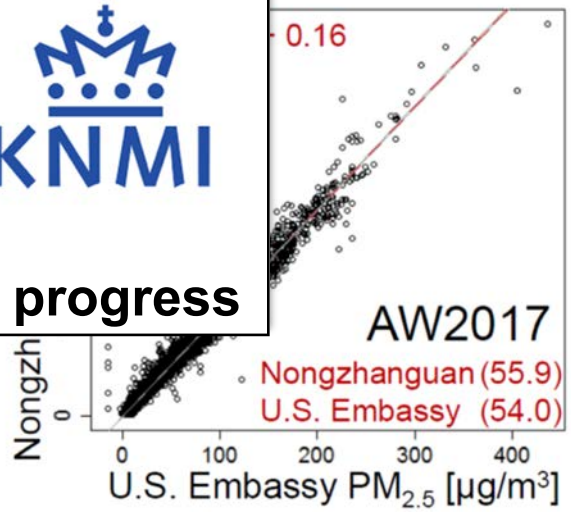
KNMI

Assessing t… with …

…North China







Tracking Success and Absence of Air Quality Policies in Cities

The Underappreciated Upper Troposphere

Assessing the UK Emission Inventory with Earth Observations

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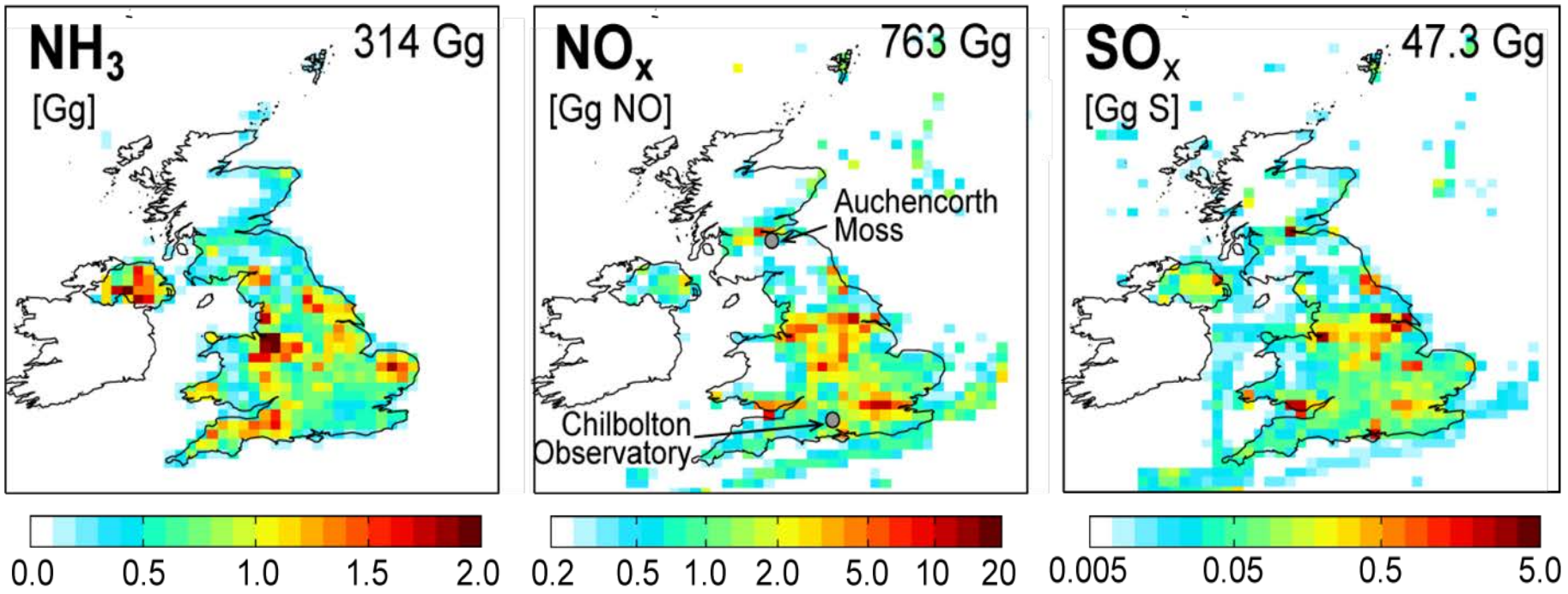
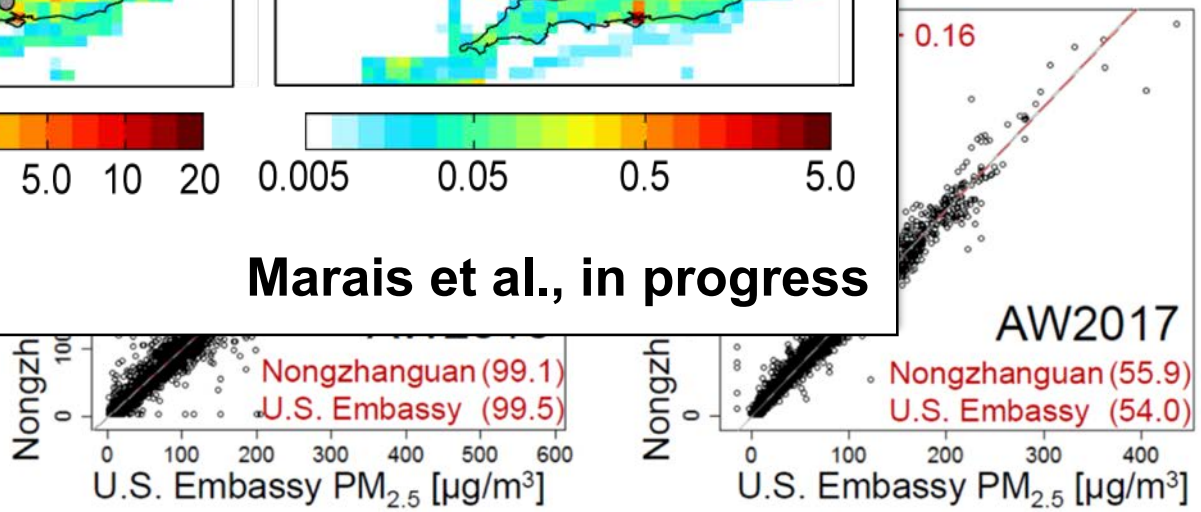


Marais et al., in progress

North China



Tracking Success and Absence of Air Quality Policies in Cities

Air pollutant	L
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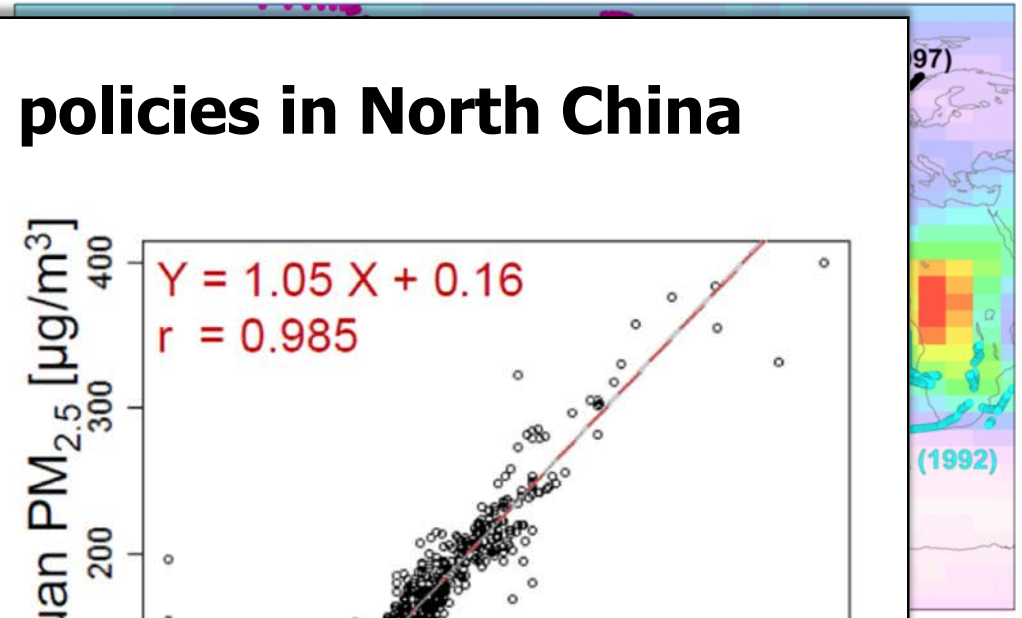
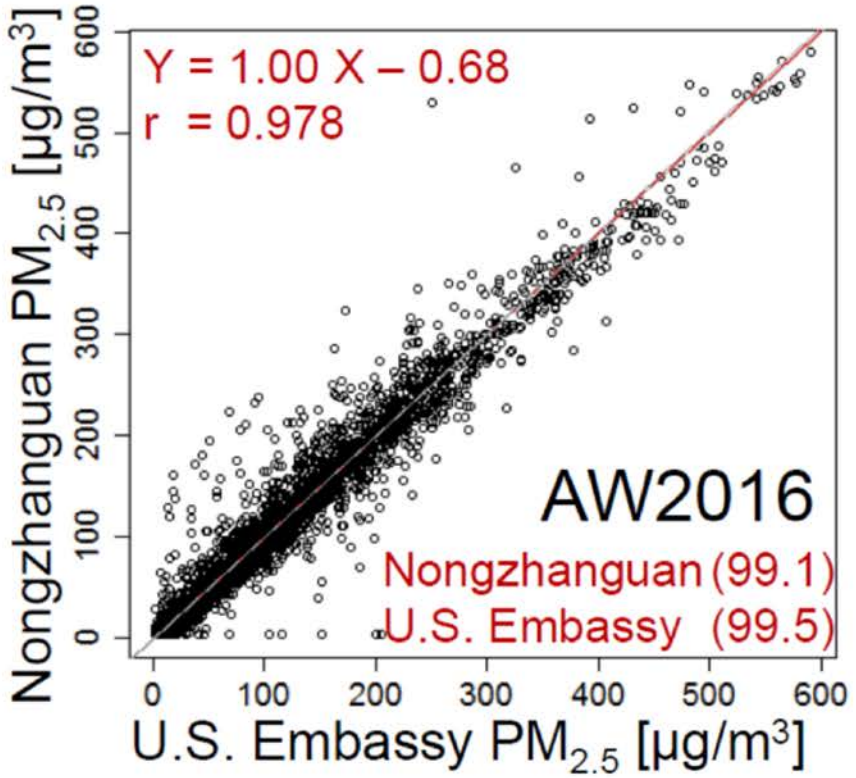
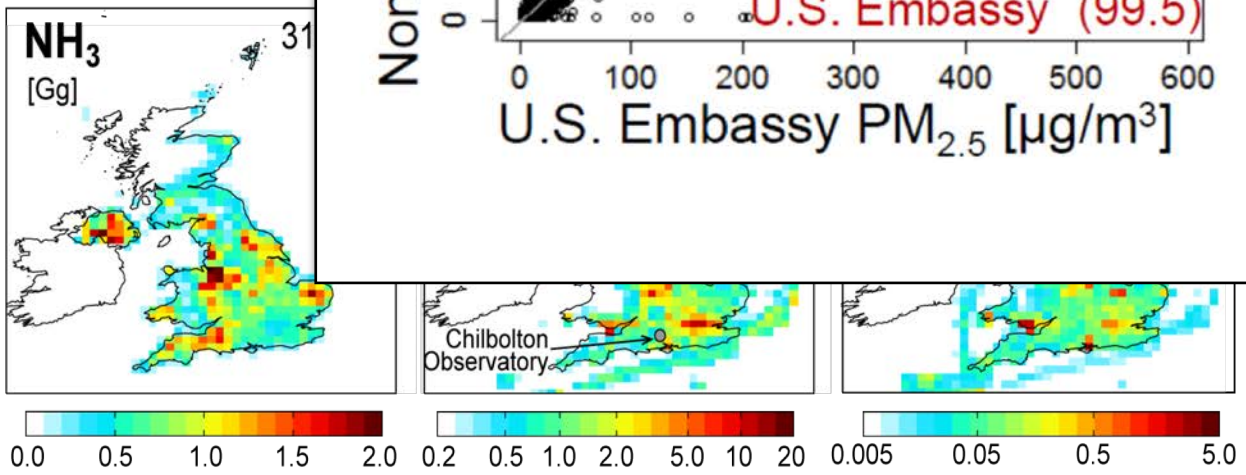


Assessing strict air quality policies in North China



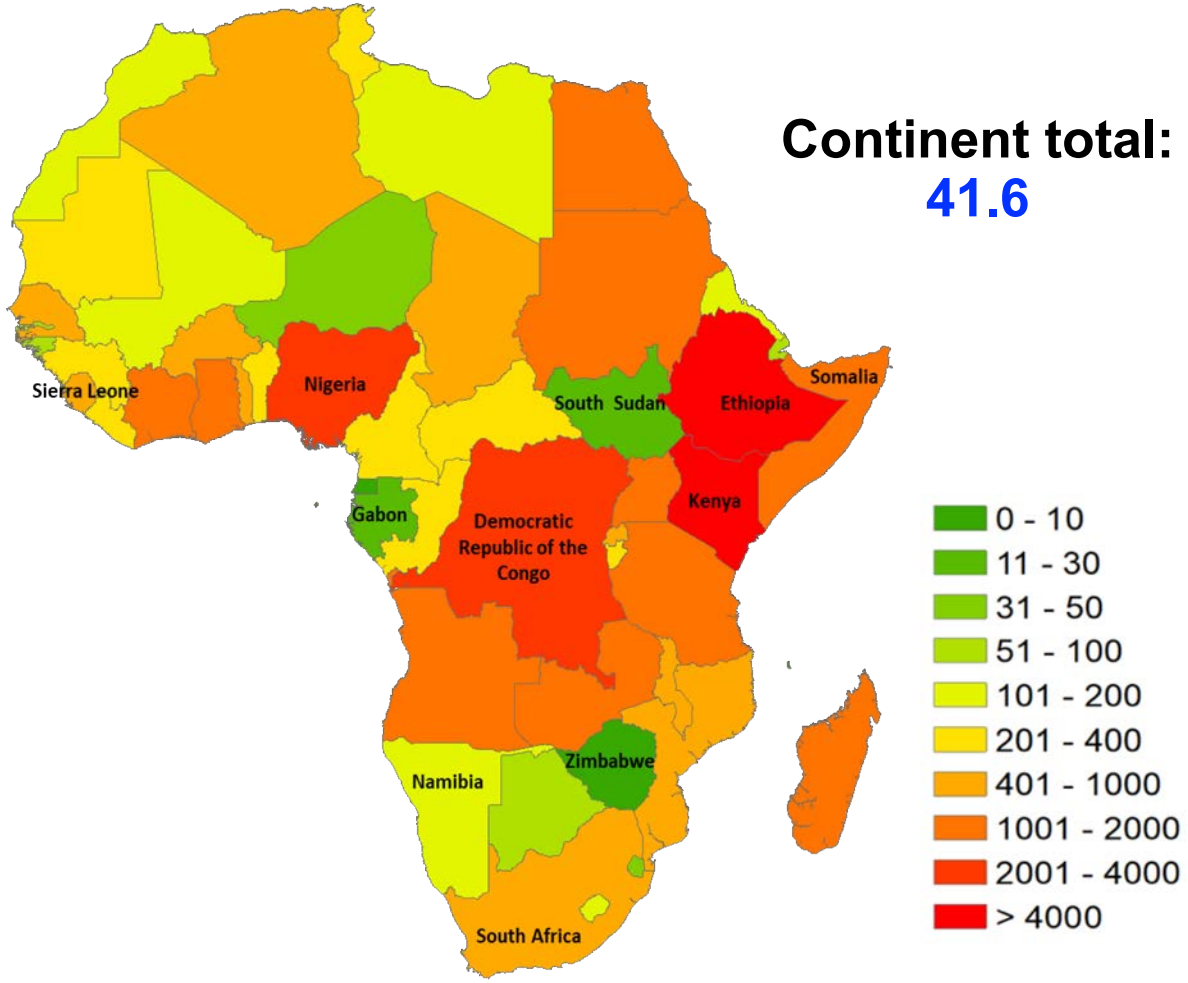
Lu et al., in progress

Assessing t… with…



The Burgeoning Charcoal Industry in Africa

Charcoal Production in 2014 [million tonnes]

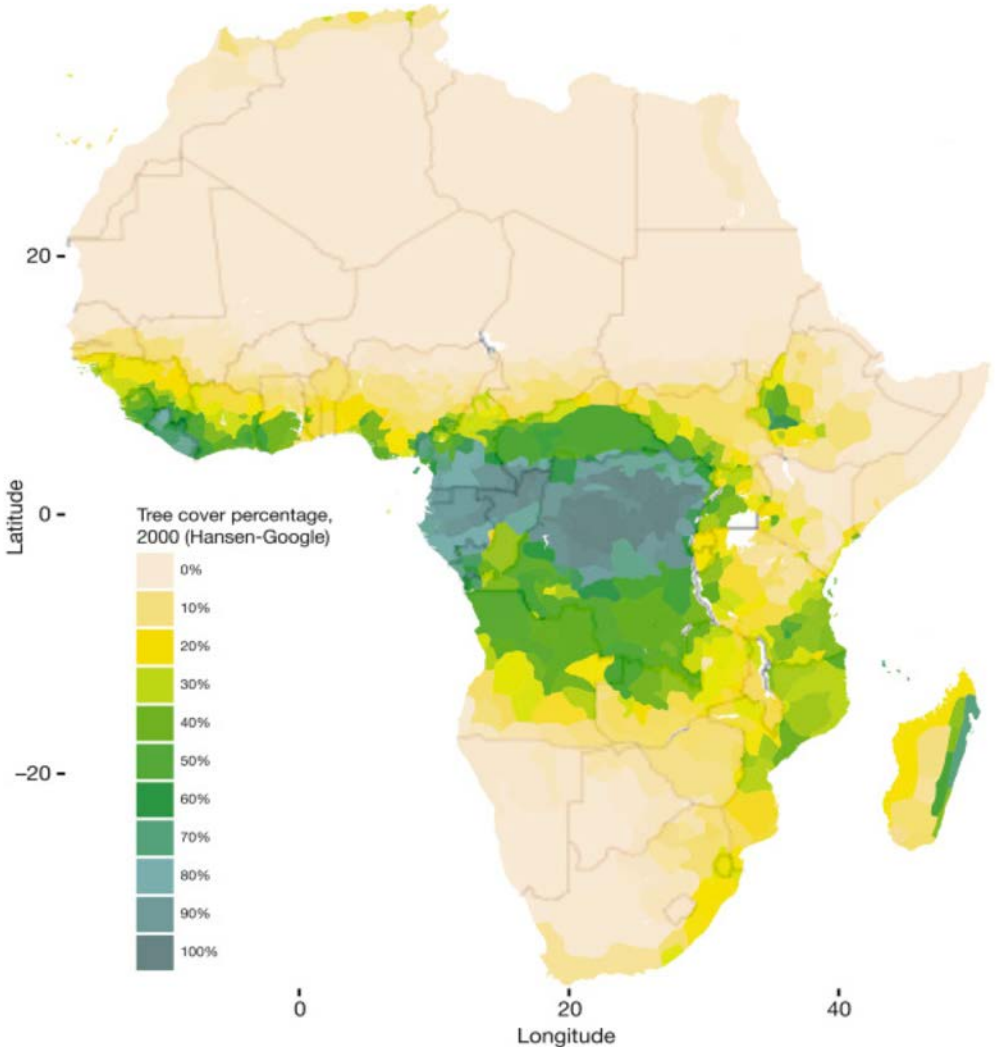


Continent total:
41.6

Data are from the UN (http://data.un.org/Explorer.aspx)

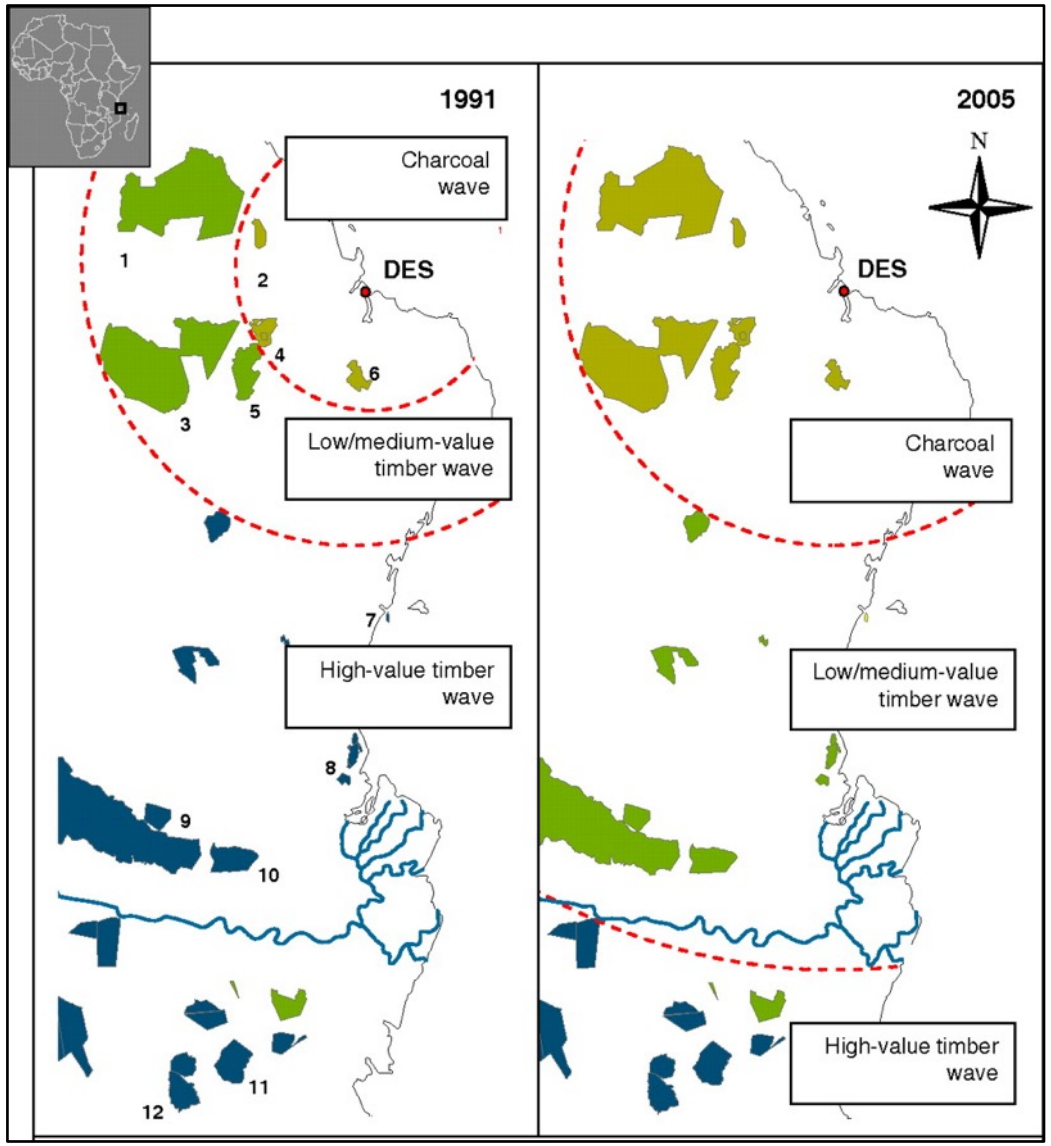
[Bockarie et al., in progress]

Percent Tree Cover in Africa



[Map: Zabala (2011). Data: Hansen et al. (2013)]

Rapid Expansion in Charcoal Producing Zones



[Ahrends et al., 2010]

Major driver of forest loss/degradation

[https://www.worldatlas.com]

Contributes Outdoor and Indoor Air Pollution

... during charcoal production with earth kilns

$PM_{2.5}$ > 100 μg m^{-3}

[https://www.smallstarter.com]

[https://blog.worldagroforestry.org/]

... and during charcoal use for cooking

$PM_{2.5}$ > 400 μg m^{-3}

[https://www.economist.com/]

[https://envirofit.org/]

Mapping Charcoal Industry Activities (Fuel Use)

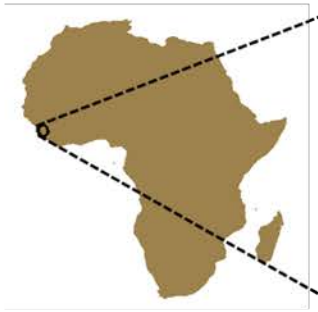
Produce

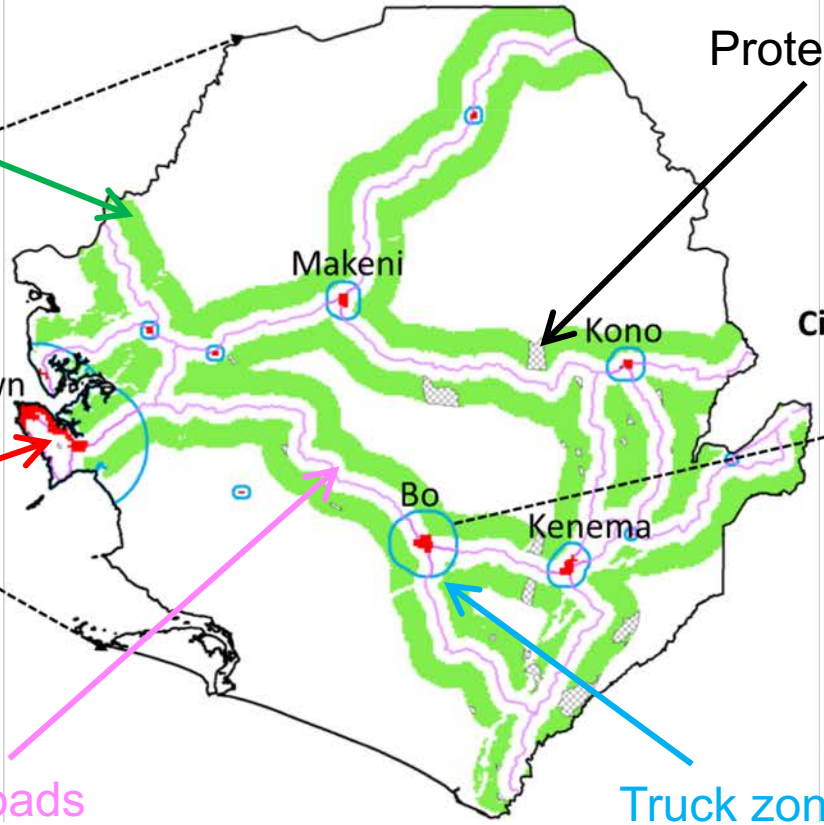
Transport

Use

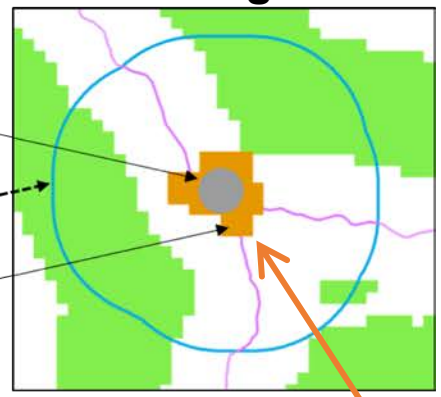
Rural production zones

Protected areas





Bo city centre and surrounding slums



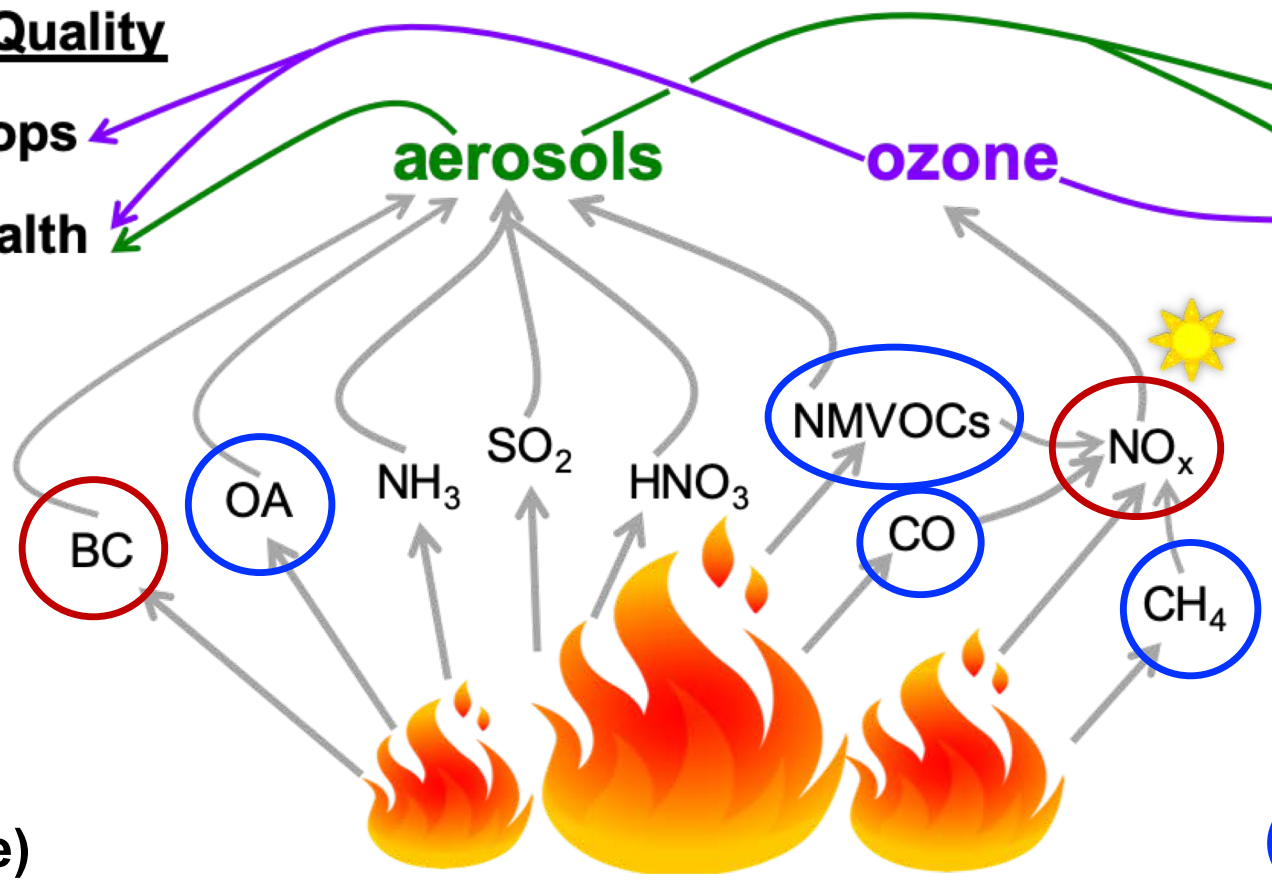
Urban centres

Major roads

Truck zones

Plastic burning to initiate combustion limited to slums

Pollutant and Precursor Emissions from Charcoal

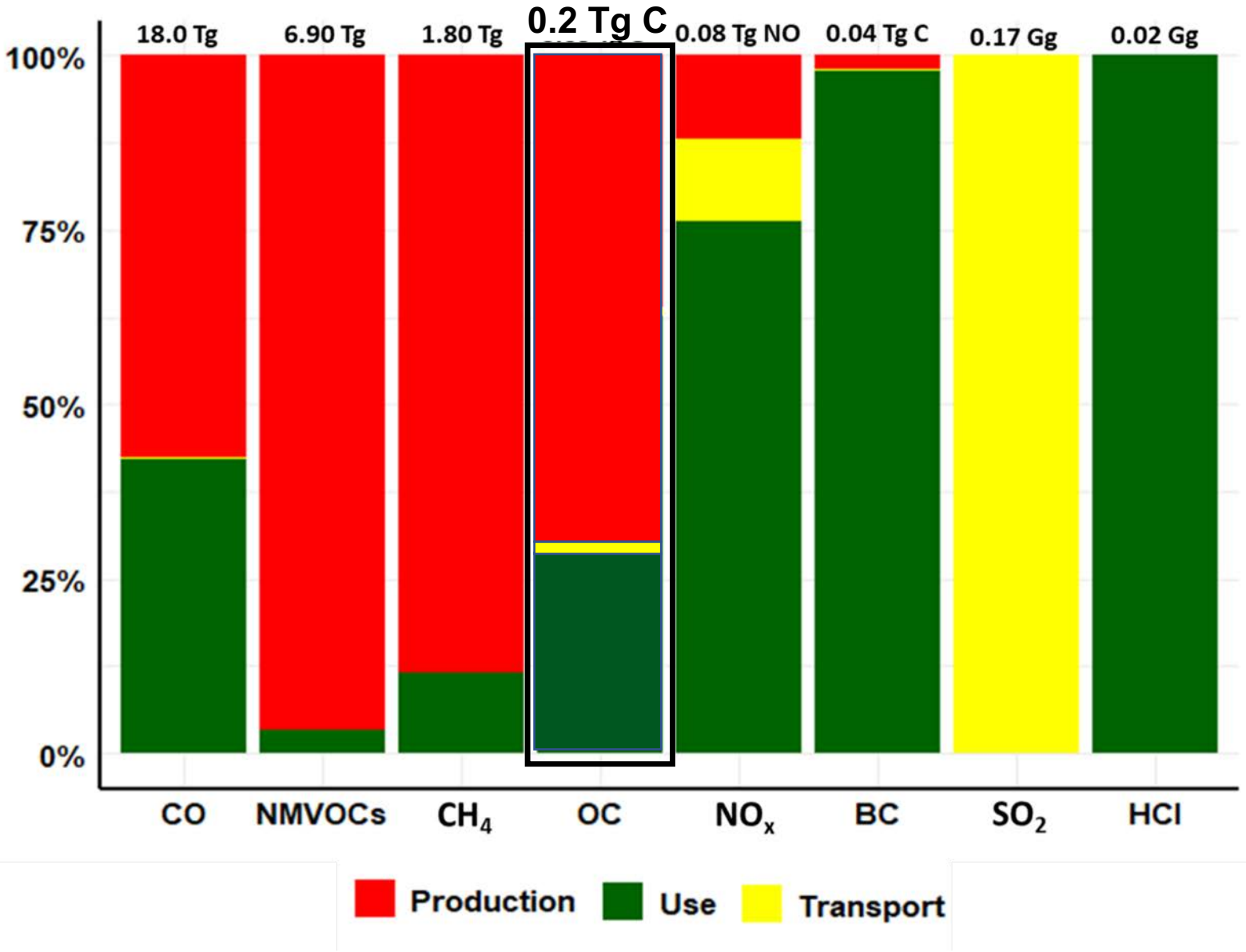


Efficient (use)

Inefficient (production)

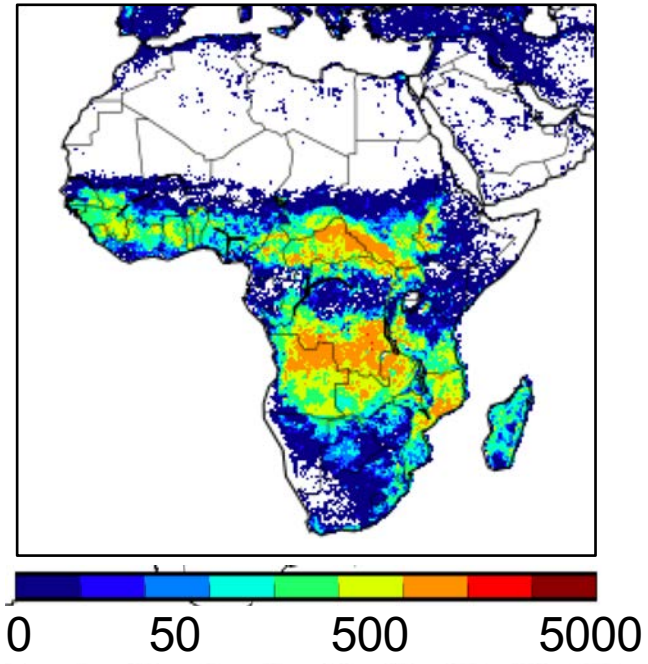
Charcoal Activities and Pollutant Emissions

Total and Relative Emissions



Comparison to Open Fires

Inventory (GFED4) carbon emissions
[g C m^{-2} $year^{-1}$]



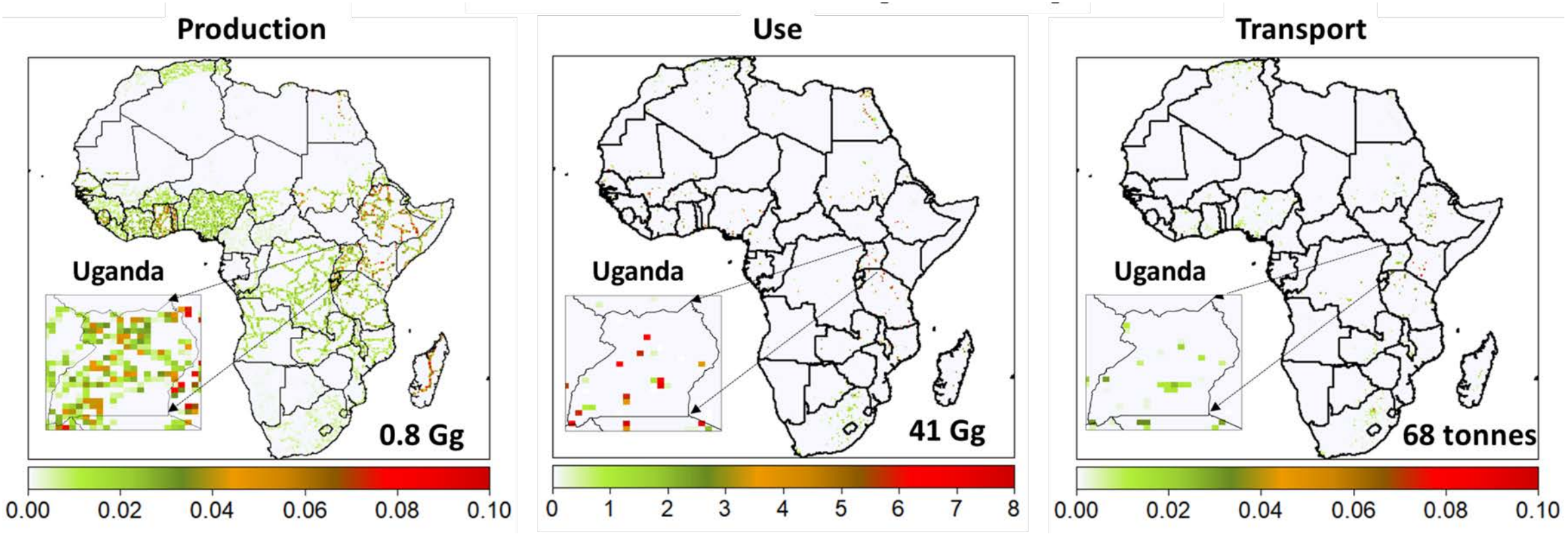
[https://daac.ornl.gov/]

CH_4: 4.6 Tg
BC: 0.81 Tg C
CO: 136 Tg
OC: 5.6 Tg C

Spatial Distribution of Emissions

Apply reported emission factors of air pollutants to mapped activities

Black carbon emissions at 0.1° × 0.1° grid for 2014 [tonnes per year]



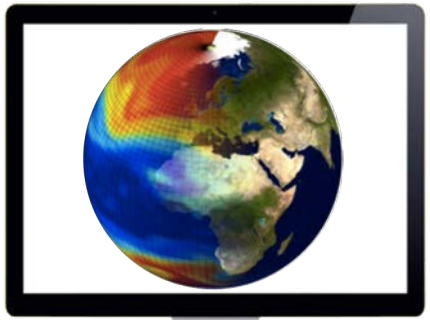
Emissions on a trajectory to double by 2030

Quantify the Contribution to Air Pollution and Climate Change

Coupled 3D atmospheric chemistry and radiative transfer models

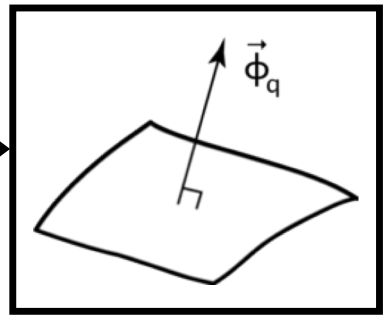
Meteorology
(NASA GMAO)

GEOS-Chem

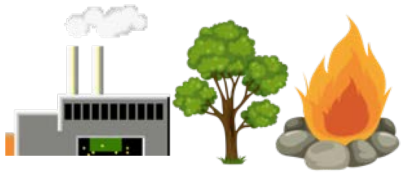


Chemistry
Transport
Dry/wet deposition

RRTMG



Radiative Transfer



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

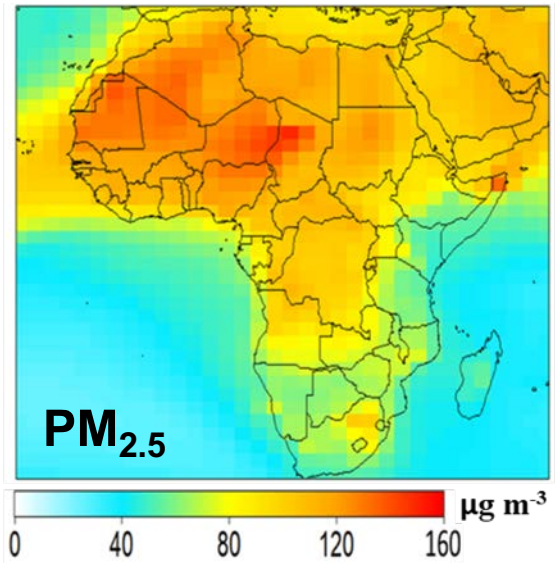
3D concentrations of ozone and aerosols

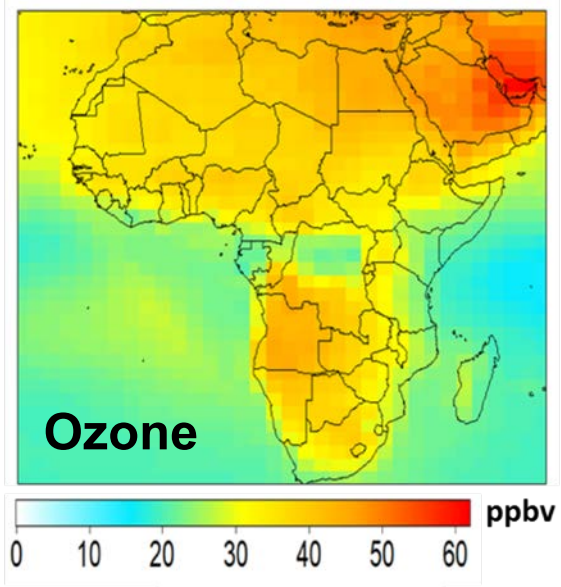
Atmospheric heat fluxes due to ozone and aerosols

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

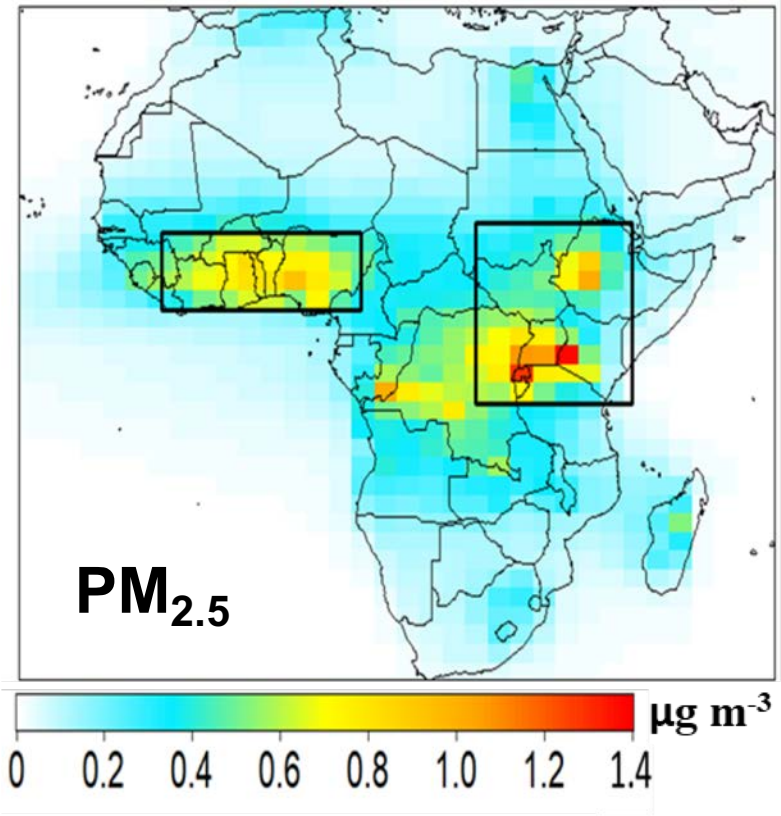
Total and Charcoal Industry Surface $PM_{2.5}$ and Ozone

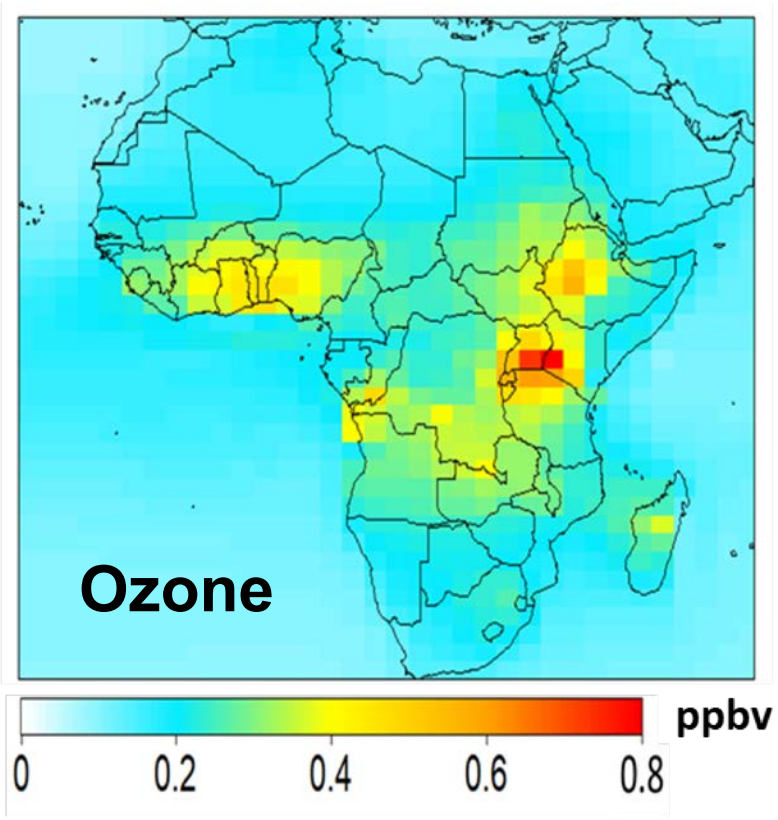
$PM_{2.5}$ and Ozone from All Sources





$PM_{2.5}$ and Ozone from the Charcoal Industry





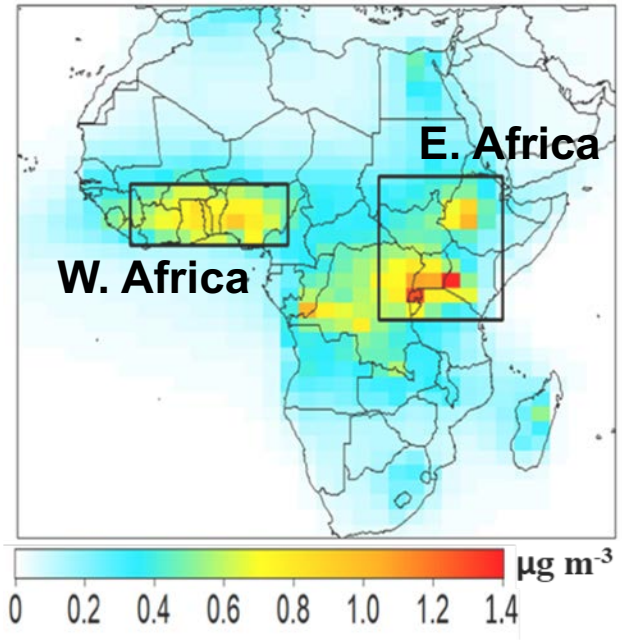
Peaks in urban areas in East, West and Central Africa, as expected from spatial distribution of emissions

$PM_{2.5}$ > 0.8 μg m^{-3} in East Africa has serious health implications

Increase in surface ozone is small (at most 0.8 ppbv)

Seasonality of Charcoal Surface $PM_{2.5}$ and Ozone

Charcoal industry $PM_{2.5}$

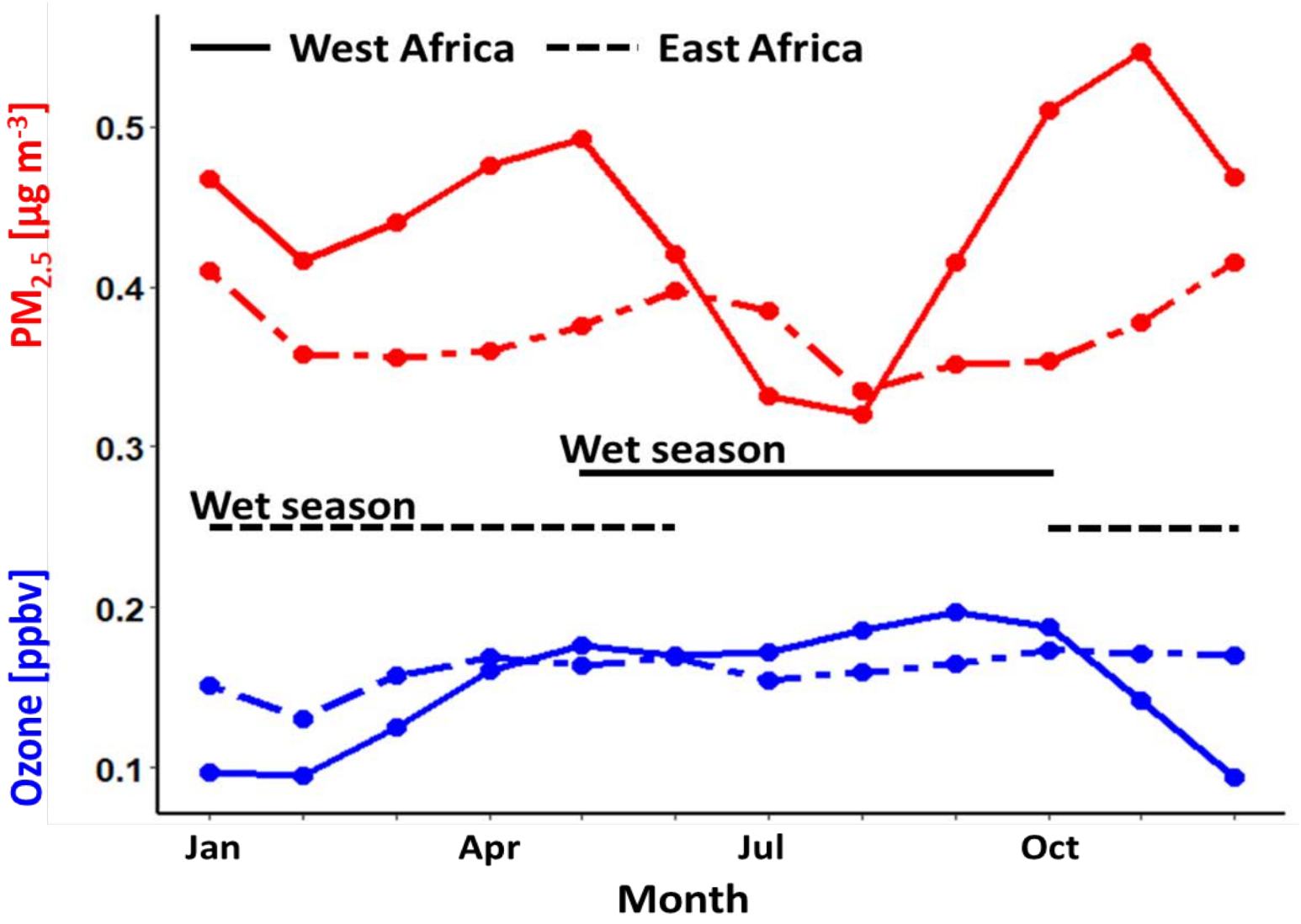


Seasonality most pronounced in West Africa

$PM_{2.5}$ seasonality due to monsoon and Harmattan winds

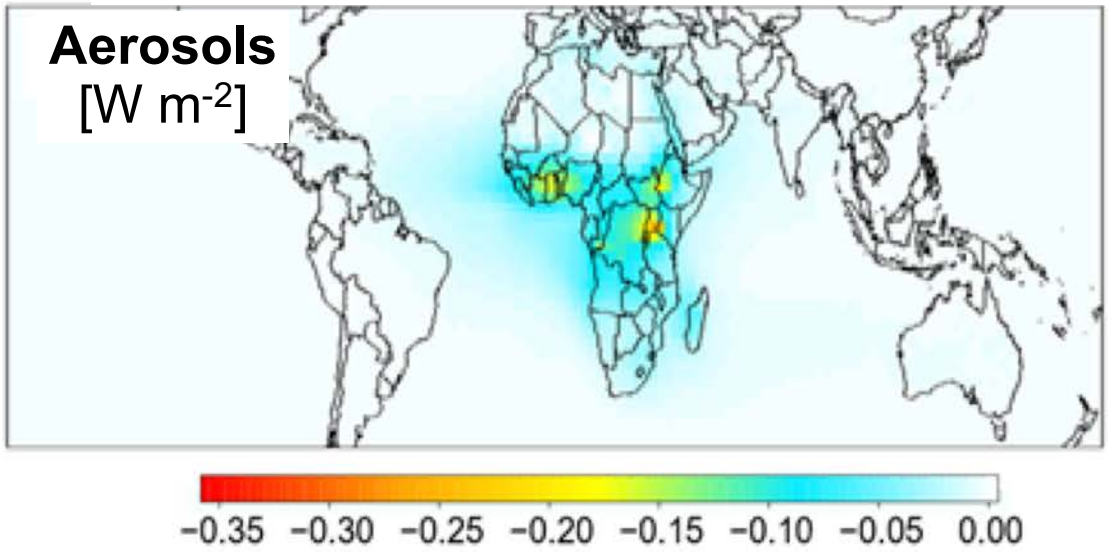
Ozone formation sensitive to NO_x in wet season

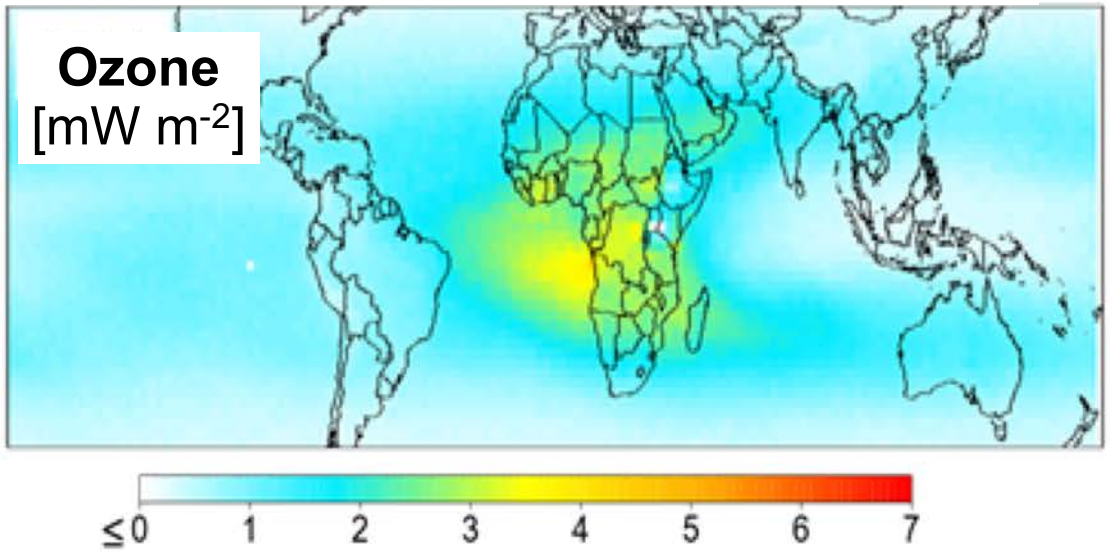
Charcoal $PM_{2.5}$ and ozone seasonality where these peak



Total and Charcoal Industry Surface $PM_{2.5}$ and Ozone

Top-of-atmosphere direct all-sky radiative forcing





Shortwave cooling

Due mostly to scattering by organic aerosols

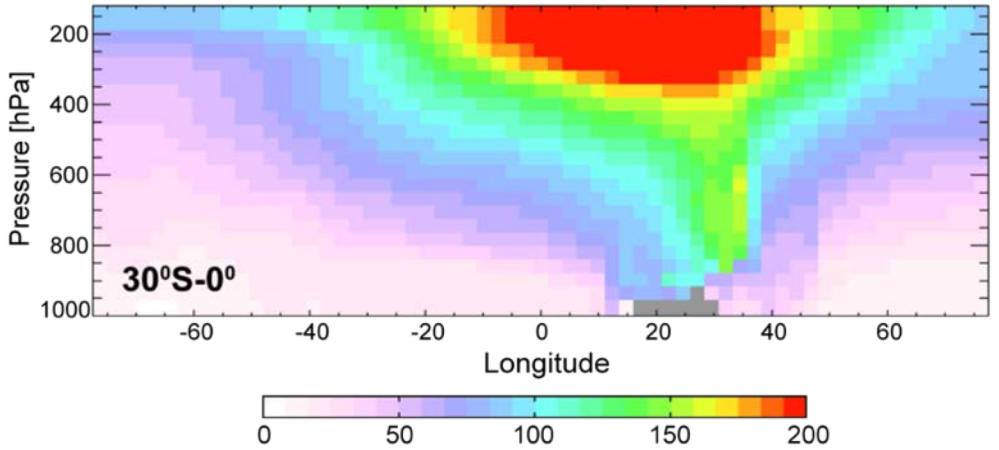
Localized effect, peaking in dense urban areas

Continent mean: **-30 mW m^{-2}**

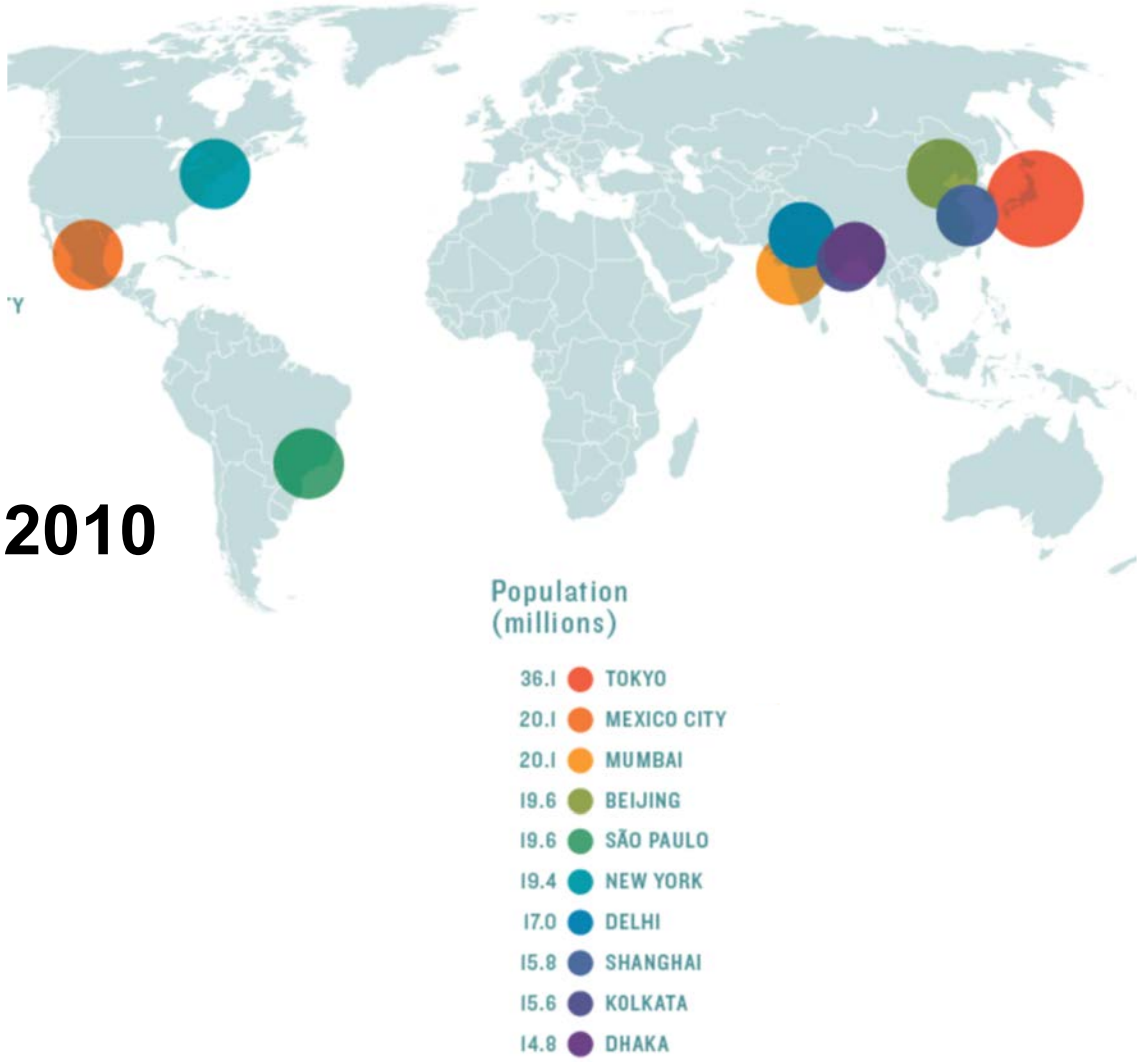
Greater response than 10% reduction in biomass burning emissions of -4 mW m^{-2} [Naik et al., 2007]

Long- and short-wave heating

Mostly due to ozone in the upper troposphere



The Environmental Impact of Charcoal will Worsen, as by 2100 the Largest Cities in the World will be in Africa



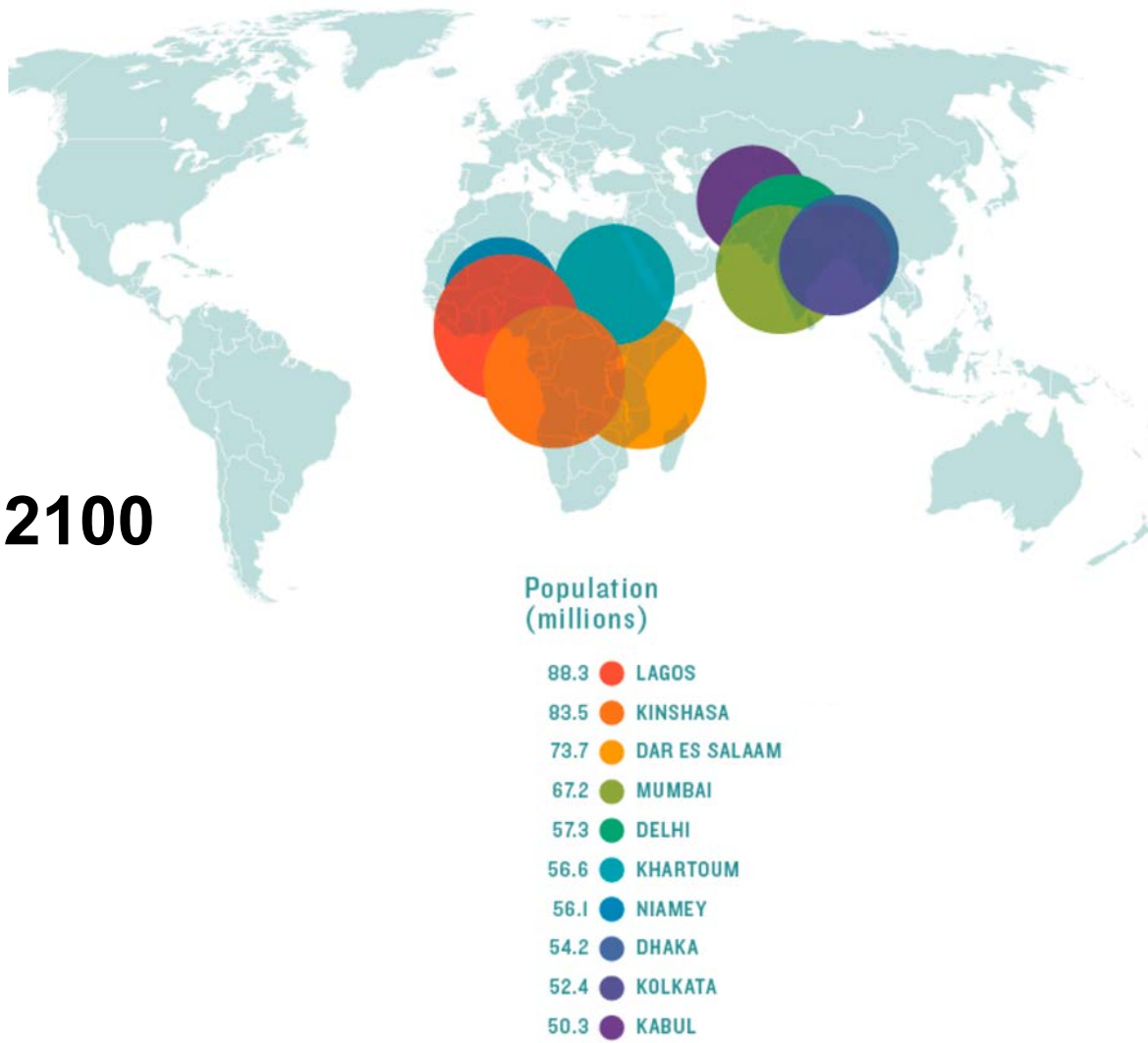


Image source: http://edge.ensia.com/here-come-the-megacities/
Data source: https://journals.sagepub.com/doi/pdf/10.1177/0956247816663557