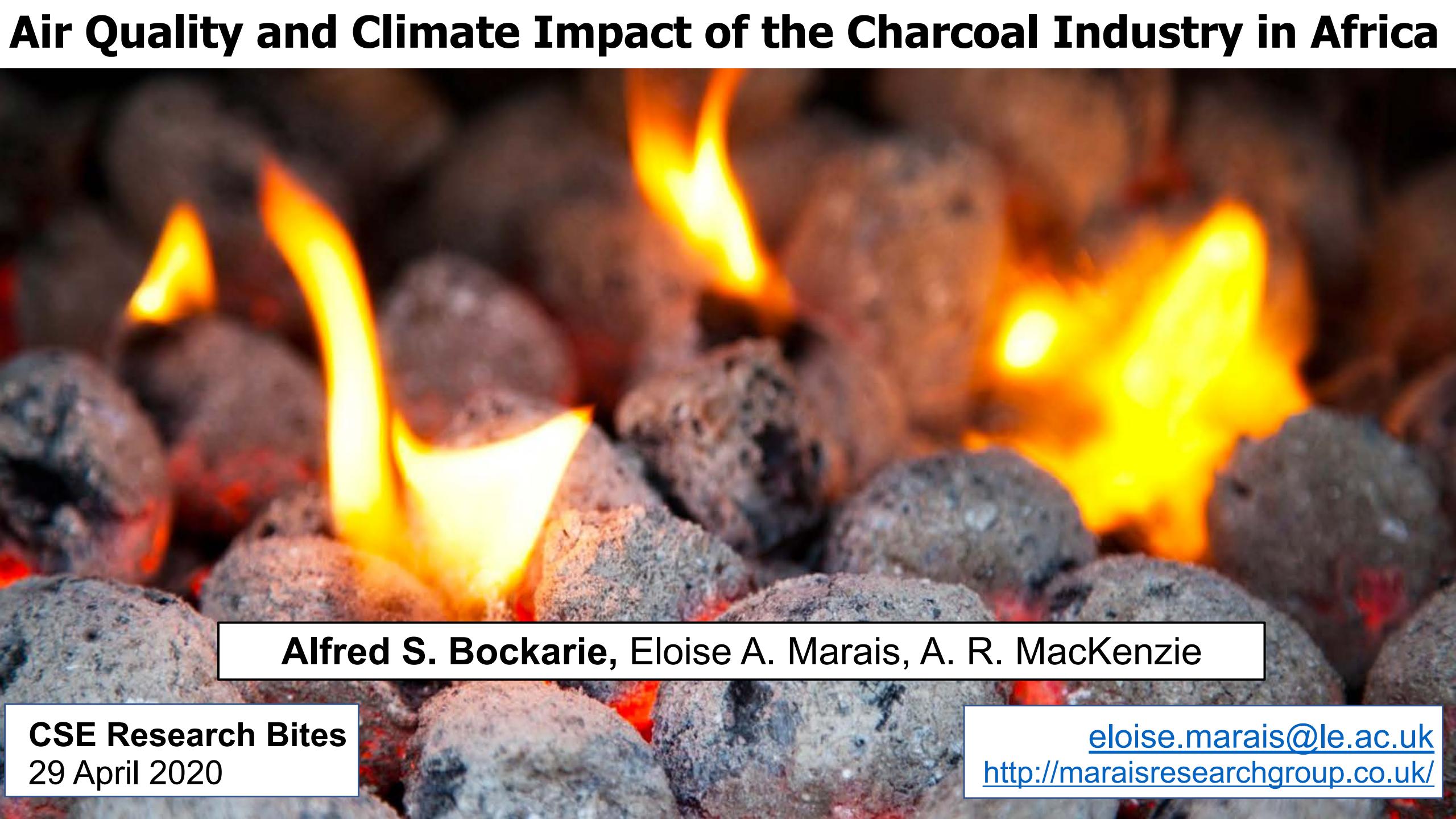
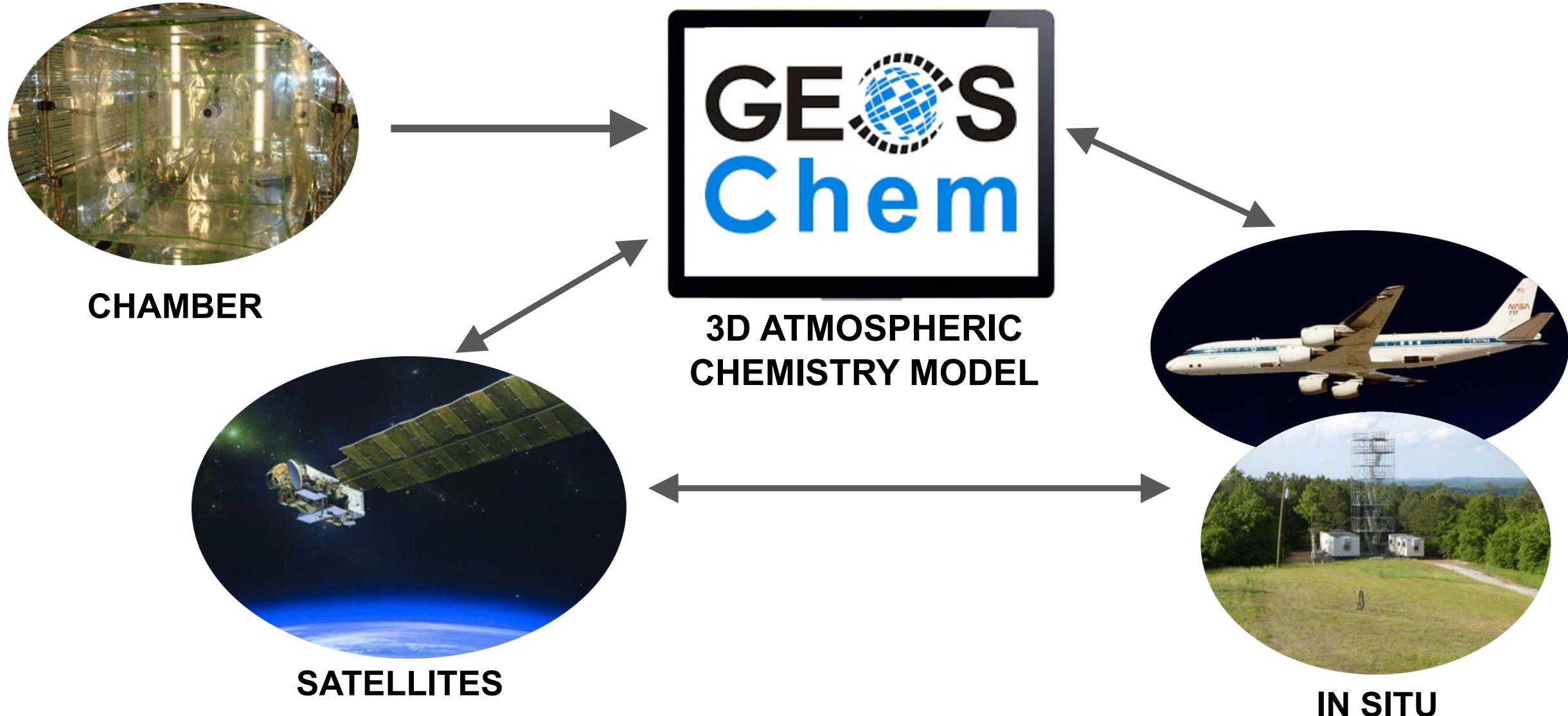


Air Quality and Climate Impact of the Charcoal Industry in Africa



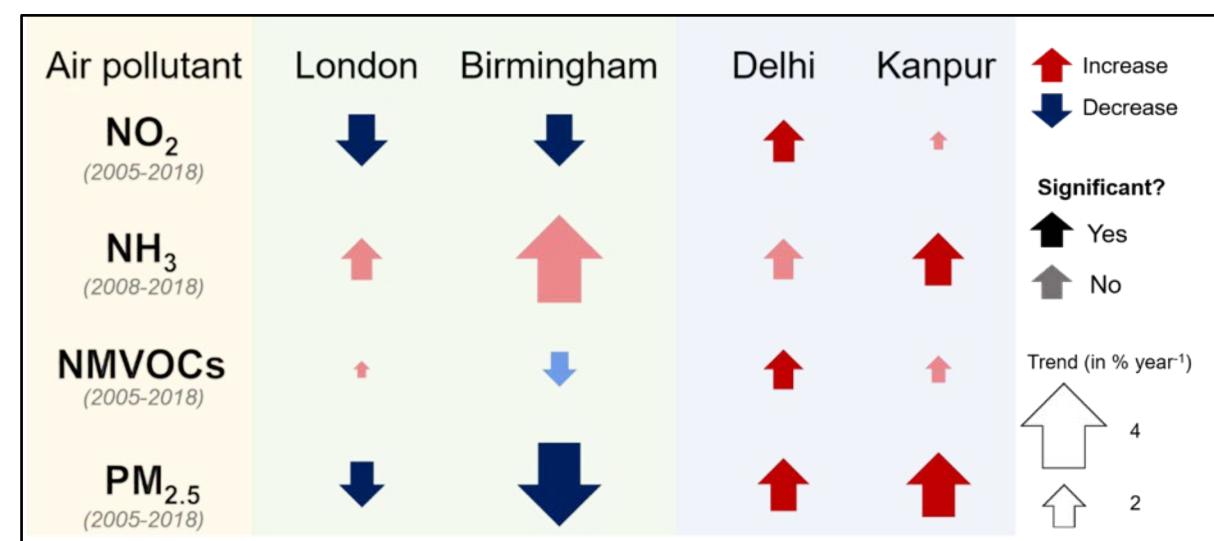
Alfred S. Bockarie, Eloise A. Marais, A. R. MacKenzie

Multiplatform Approach to Solve Issues of Pressing Need

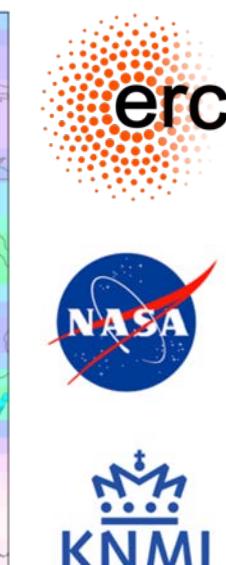
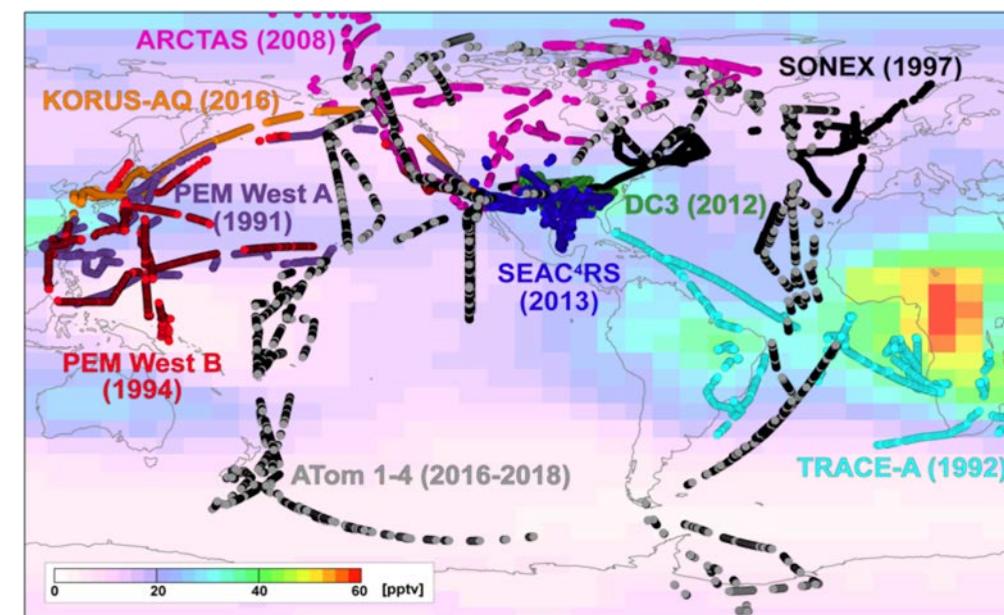


My group uses and develops state-of-science observations and tools to inform policy.

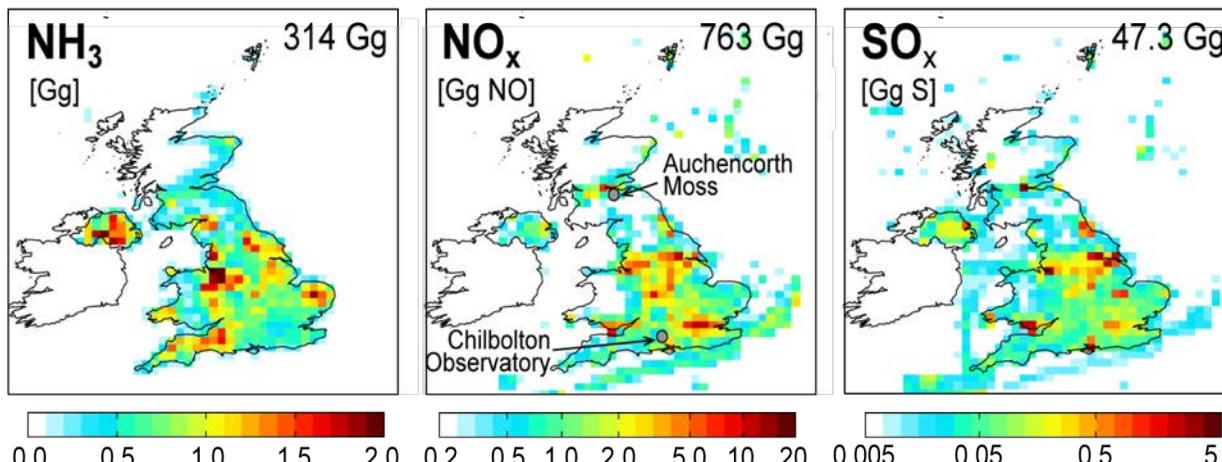
Tracking Success and Absence of Air Quality Policies in Cities



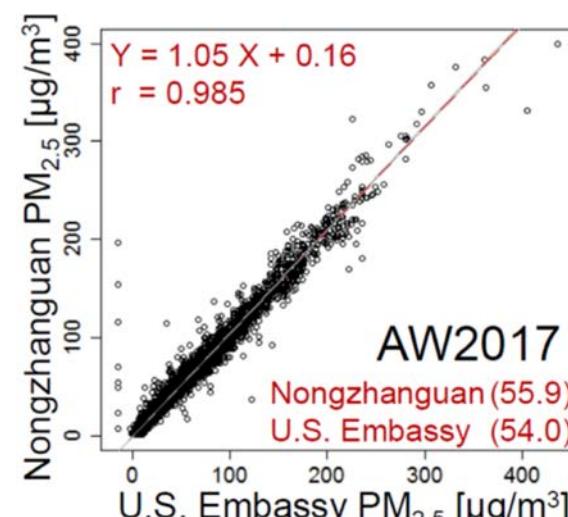
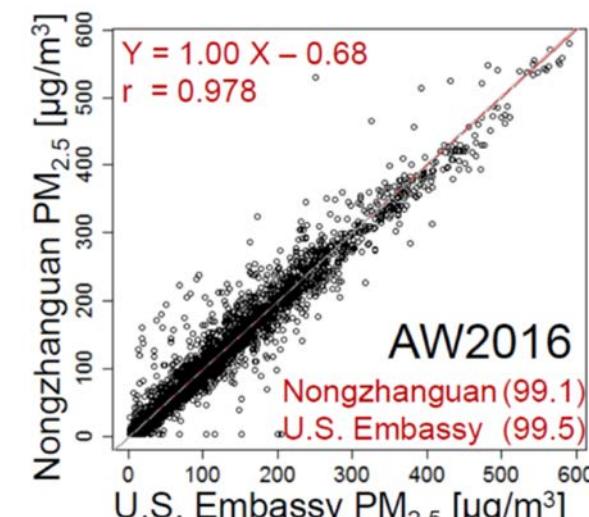
The Underappreciated Upper Troposphere



Assessing the UK Emission Inventory with Earth Observations



Assessing strict air quality policies in North China

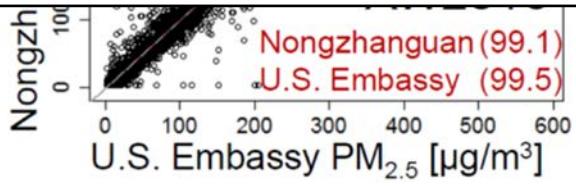
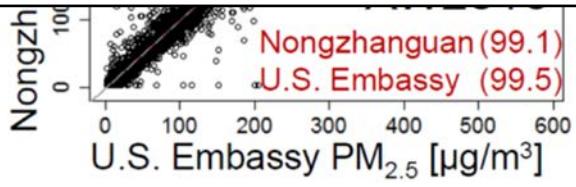
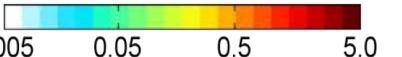
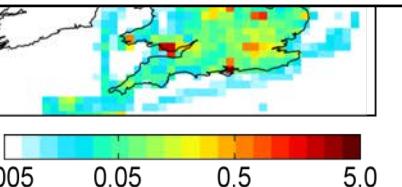
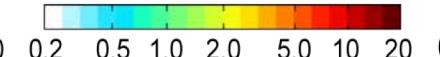
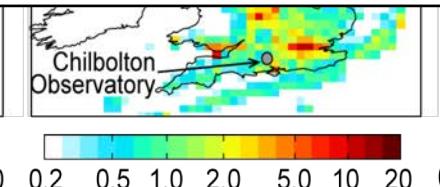
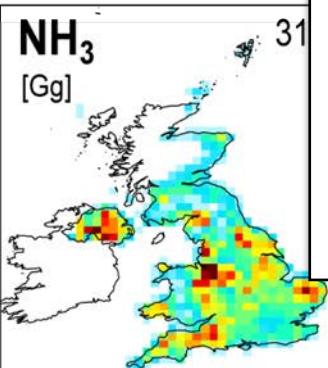
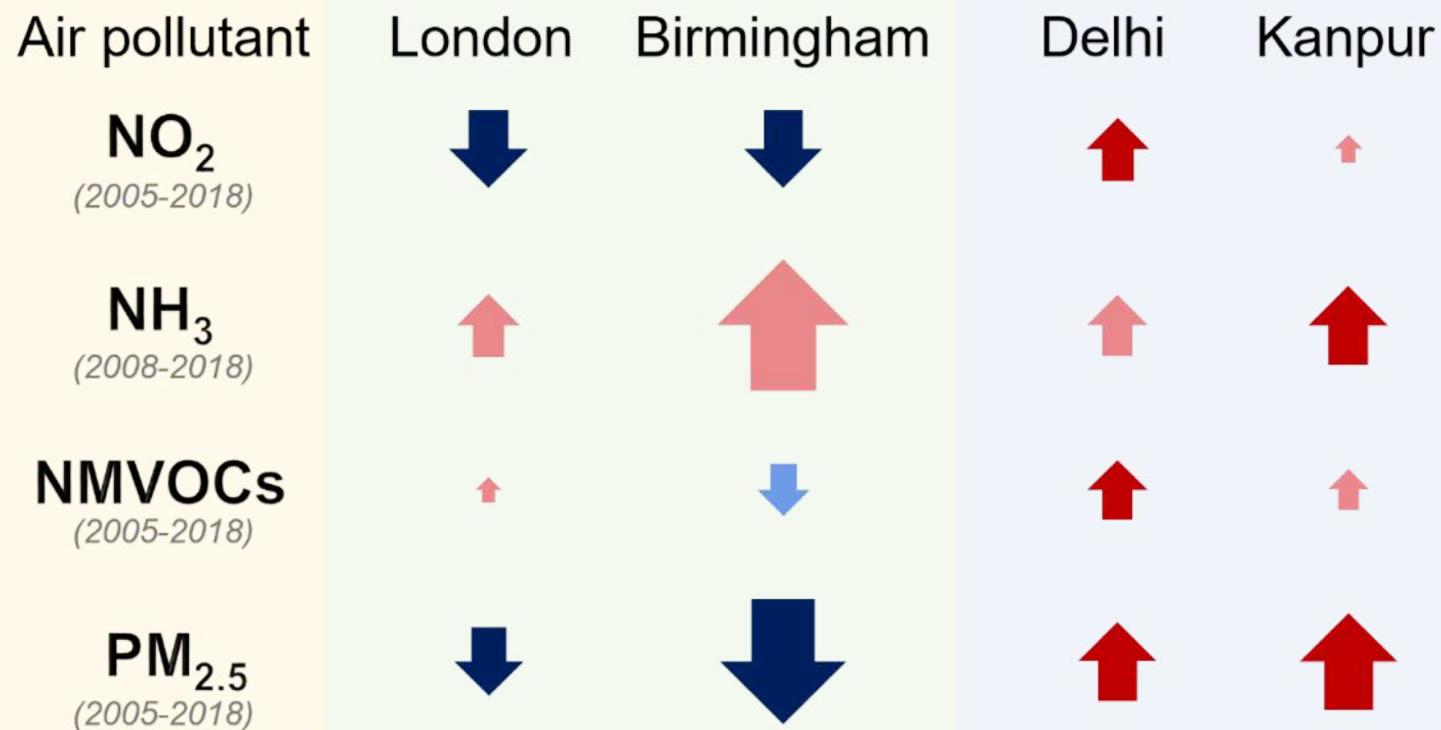




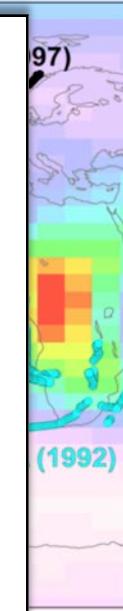
Tracking Success and Absence of Air Quality Policies in Cities



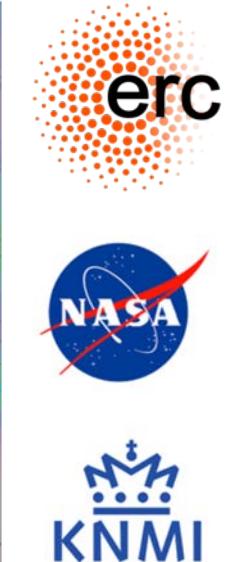
Assessing the
success of air quality
policies



Vohra et al., submitted, 2020



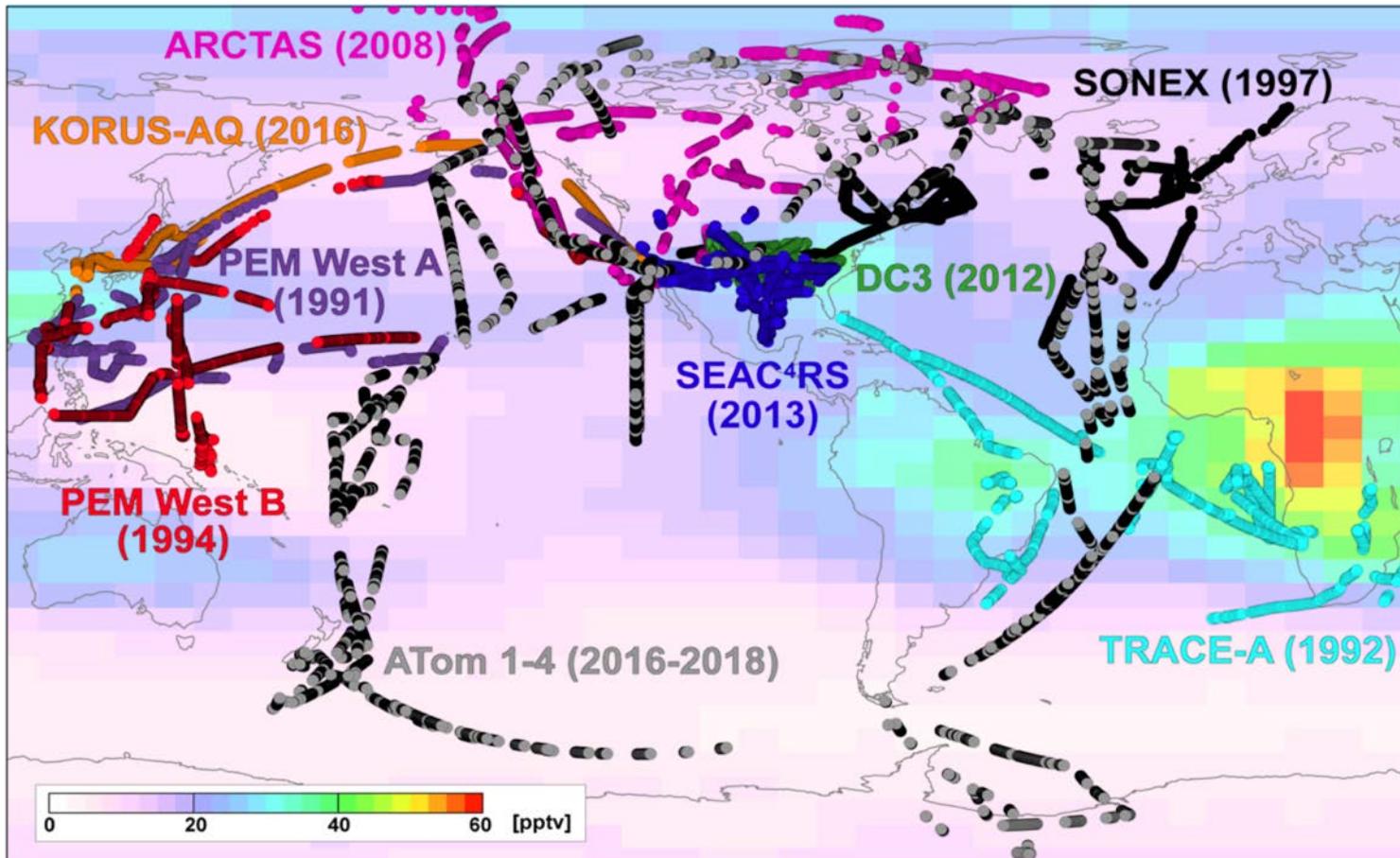
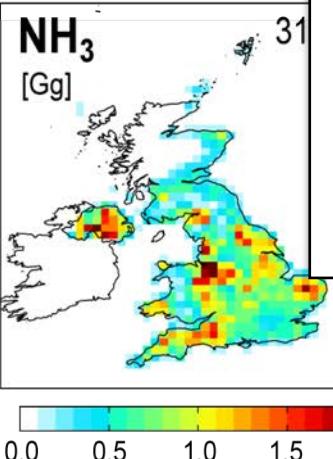
North China



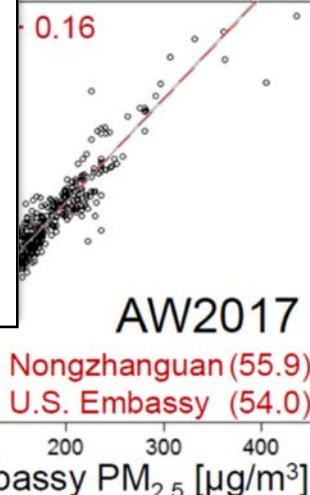
AW2017

The Underappreciated Upper Troposphere

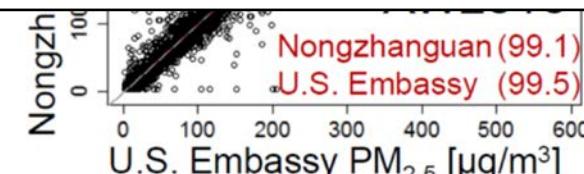
Air pollutant

 NO_2
(2005-2018) NH_3
(2008-2018)NMVOCs
(2005-2018) $\text{PM}_{2.5}$
(2005-2018)Assessing t
with

North China



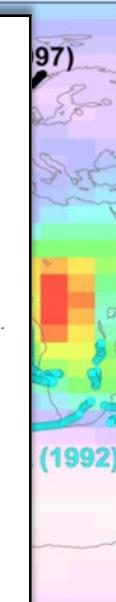
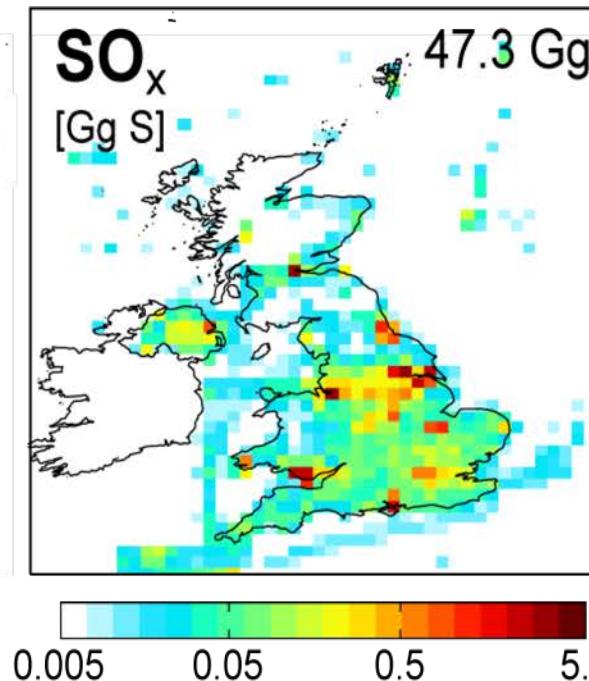
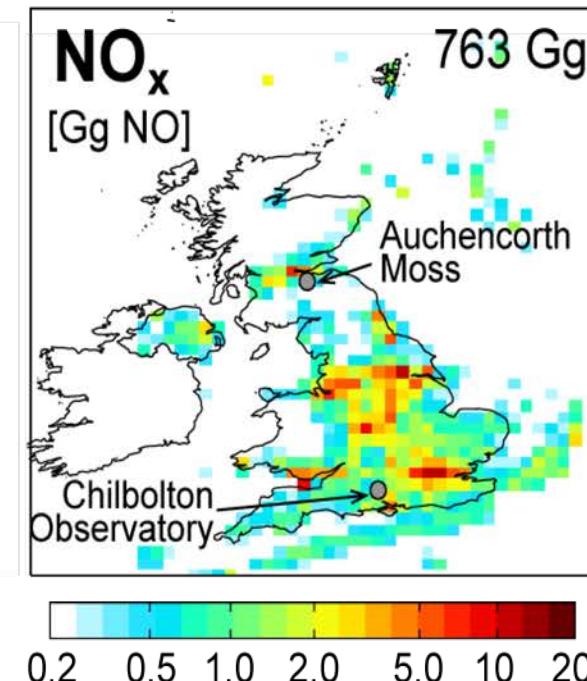
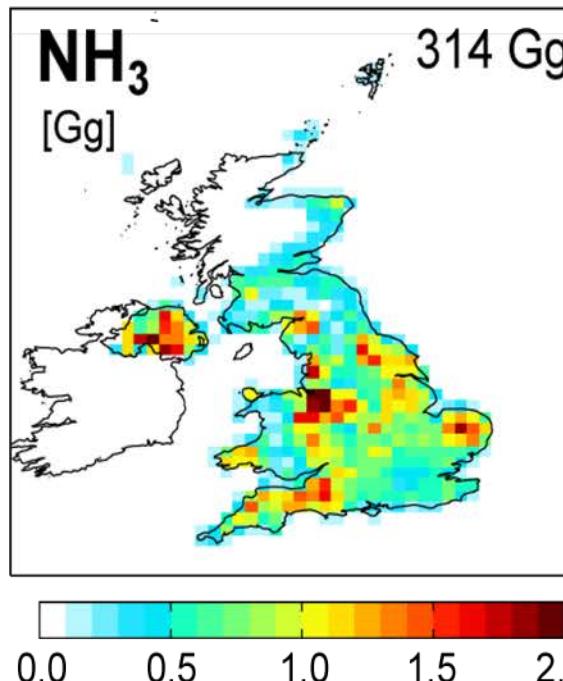
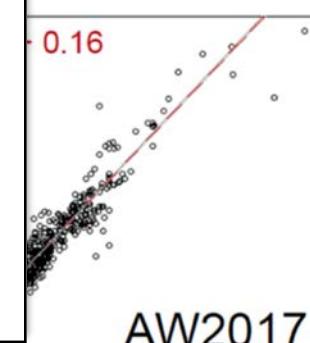
Wei et al., in progress



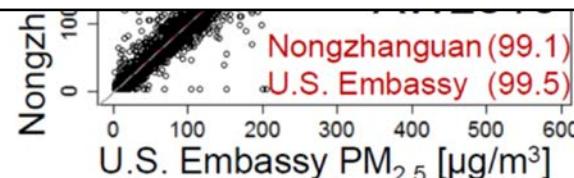
Air pollutant

 NO_2
(2005-2018) NH_3
(2008-2018)NMVOCs
(2005-2018) $\text{PM}_{2.5}$
(2005-2018)

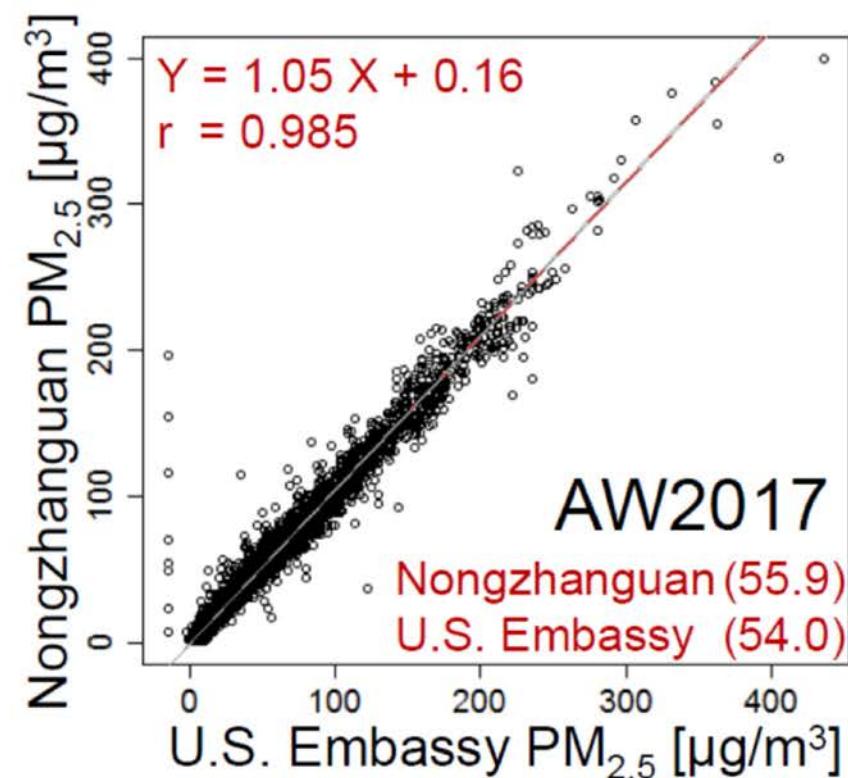
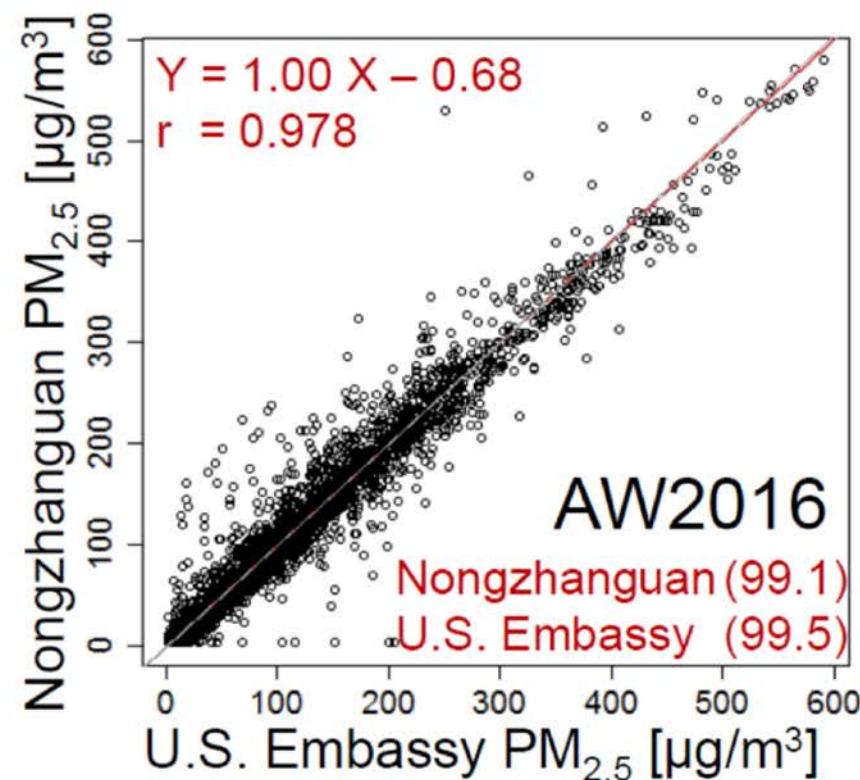
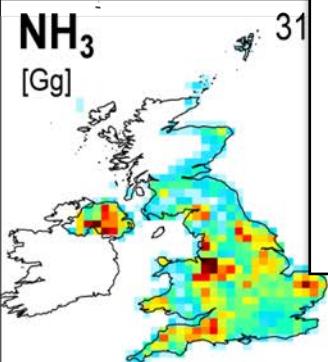
Assessing the UK Emission Inventory with Earth Observations

**North China**

AW2017

**Marais et al., in progress**

Air pollutant

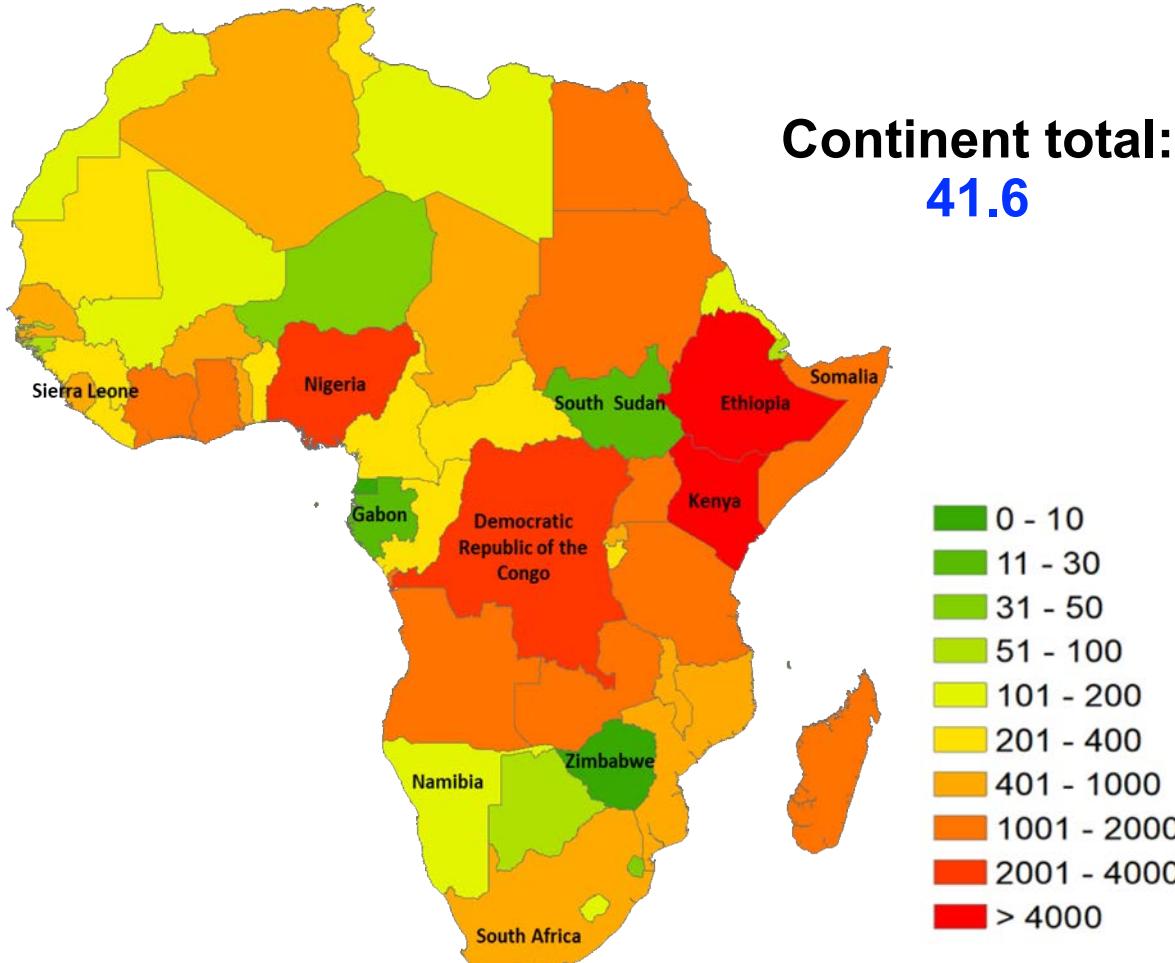
 NO_2
(2005-2018) NH_3
(2008-2018)NMVOCs
(2005-2018) $\text{PM}_{2.5}$
(2005-2018)Assessing the
with strict
air quality
policies

Lu et al., in progress



The Burgeoning Charcoal Industry in Africa

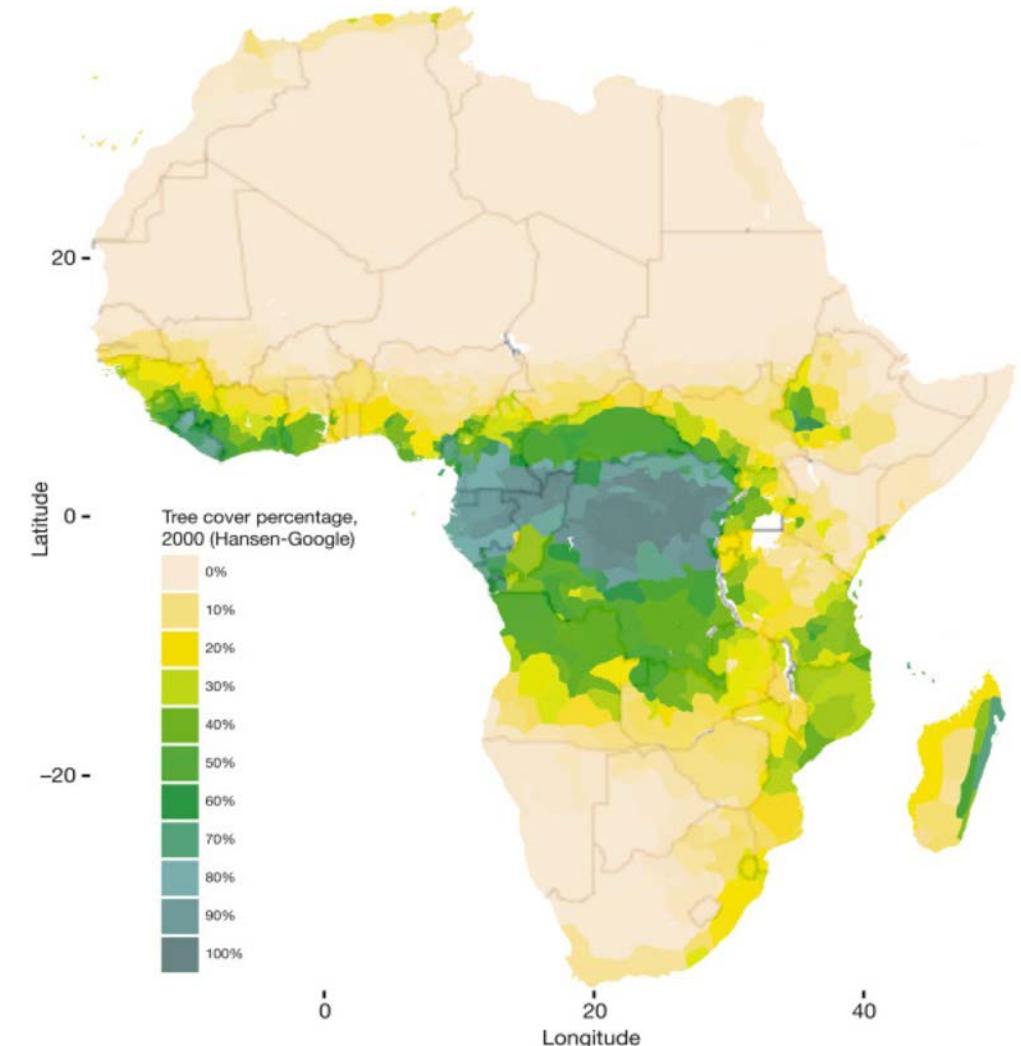
Charcoal Production in 2014 [million tonnes]



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

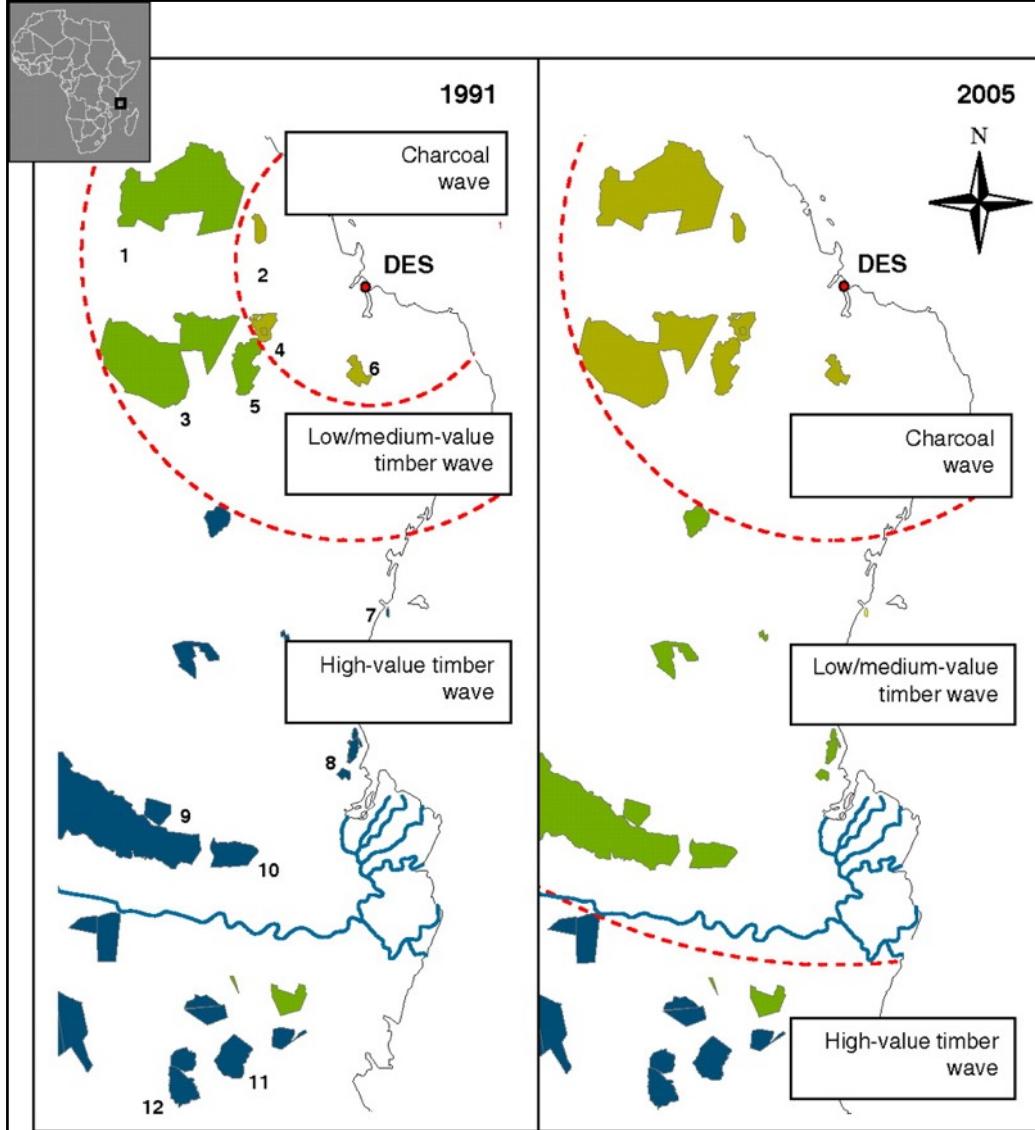
[Bockarie et al., in progress]

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



$\text{PM}_{2.5} > 100 \mu\text{g m}^{-3}$

[<https://www.smallstarter.com>]



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

... and during charcoal use for cooking



$\text{PM}_{2.5} > 400 \mu\text{g m}^{-3}$

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



[<https://envirofit.org>]

Mapping Charcoal Industry Activities (Fuel Use)

Produce



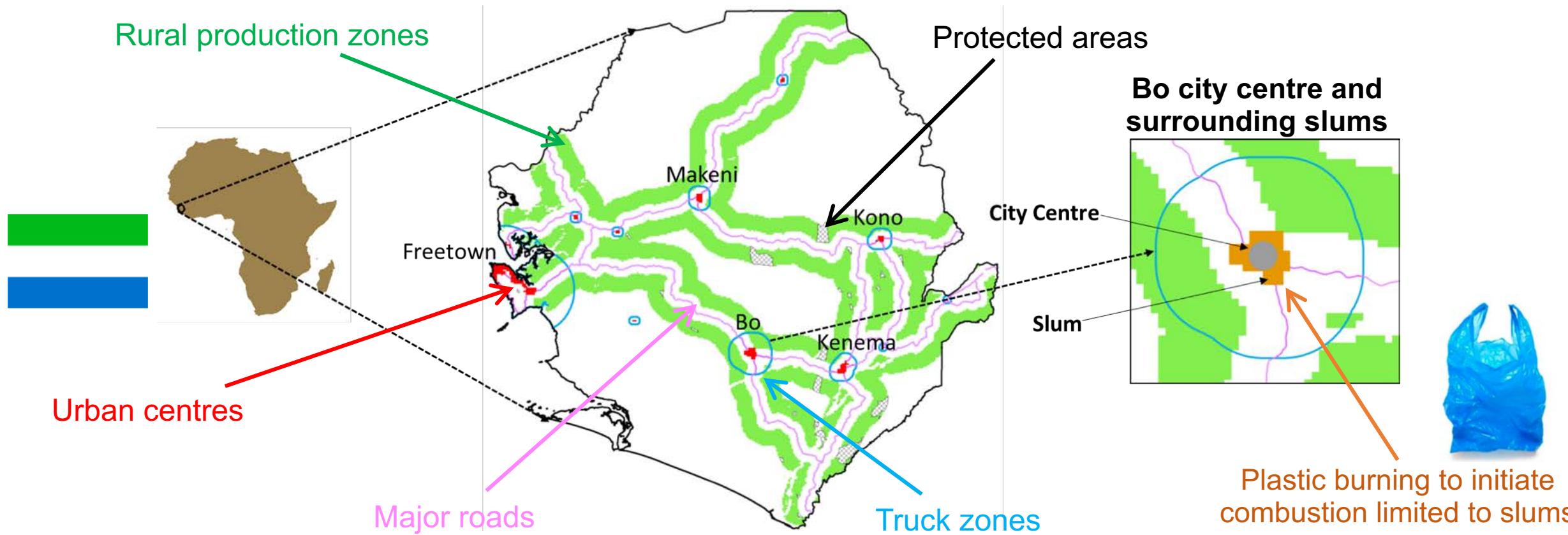
Transport



Use

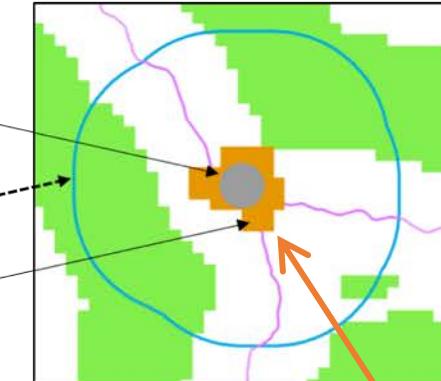


Rural production zones



Protected areas

Bo city centre and surrounding slums



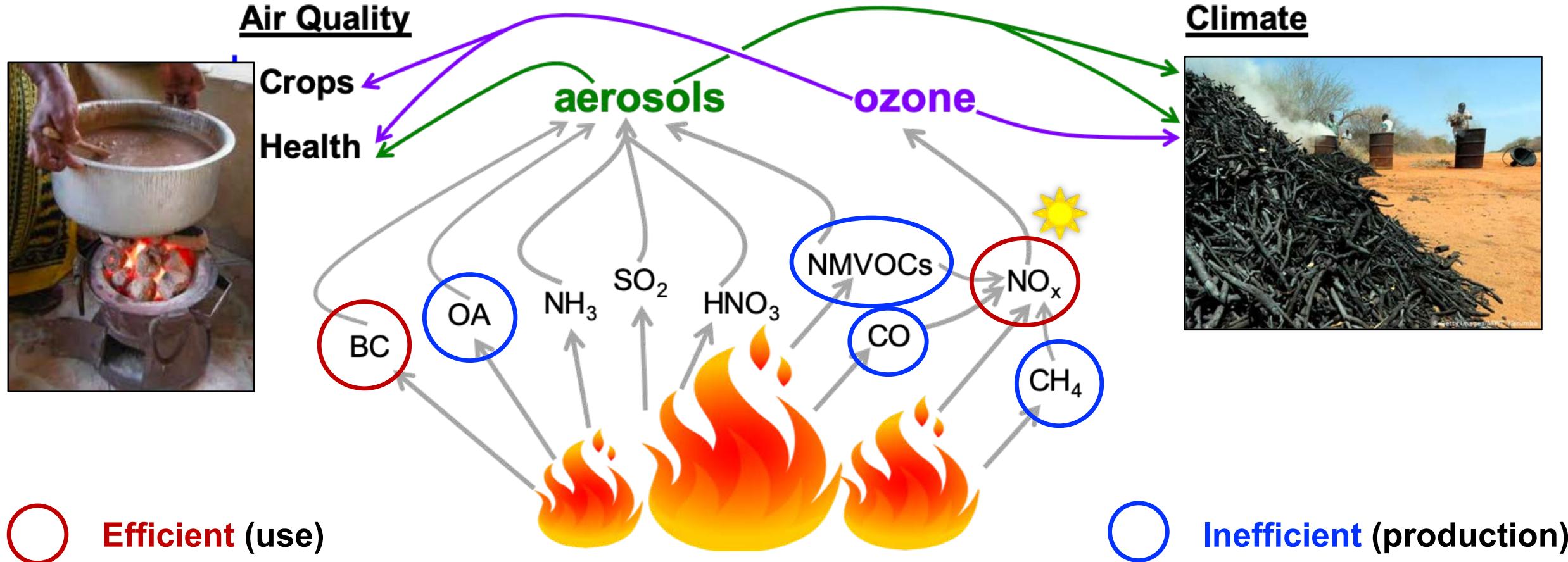
Urban centres

Truck zones

Major roads

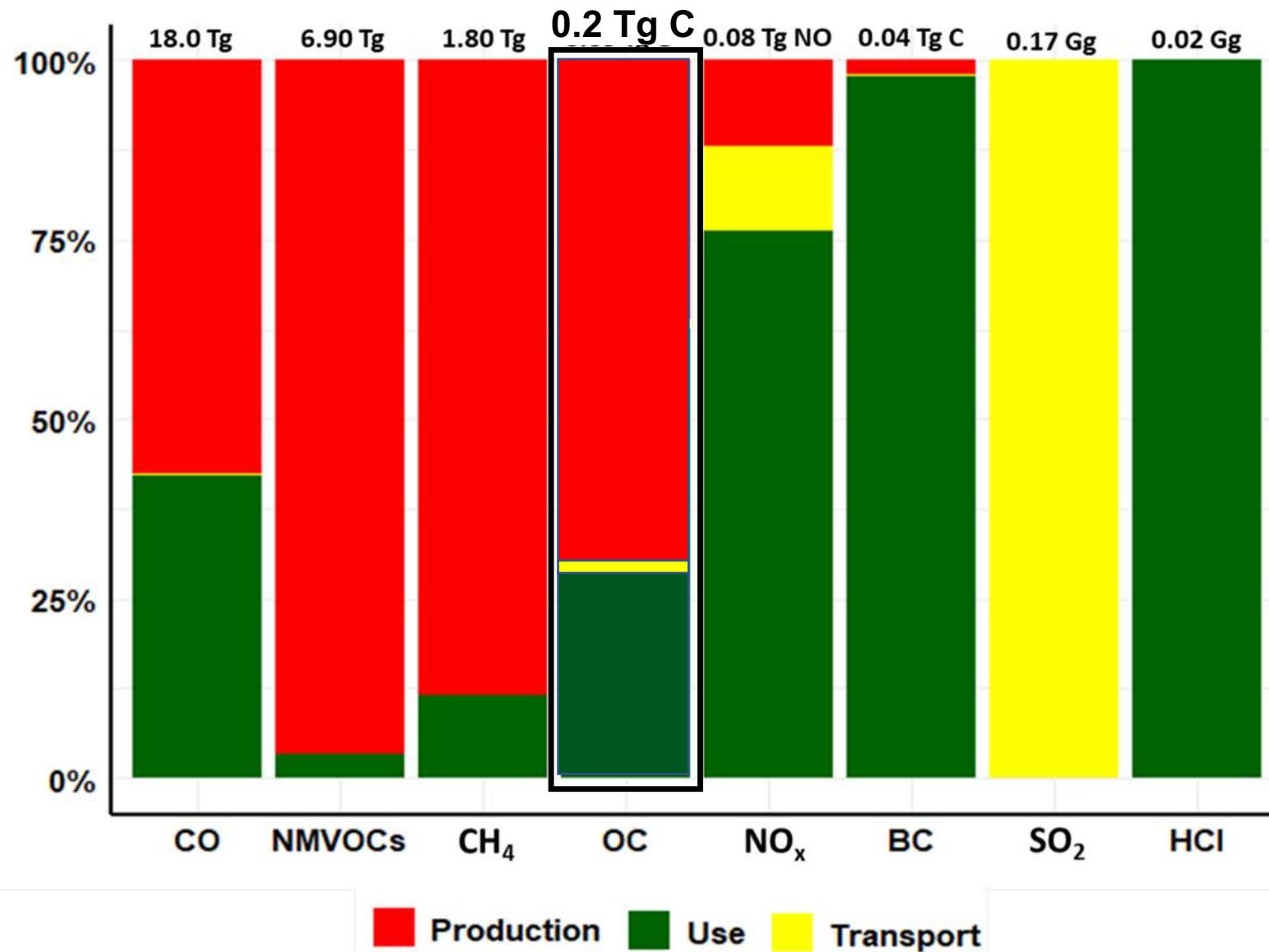
Plastic burning to initiate combustion limited to slums

Pollutant and Precursor Emissions from Charcoal



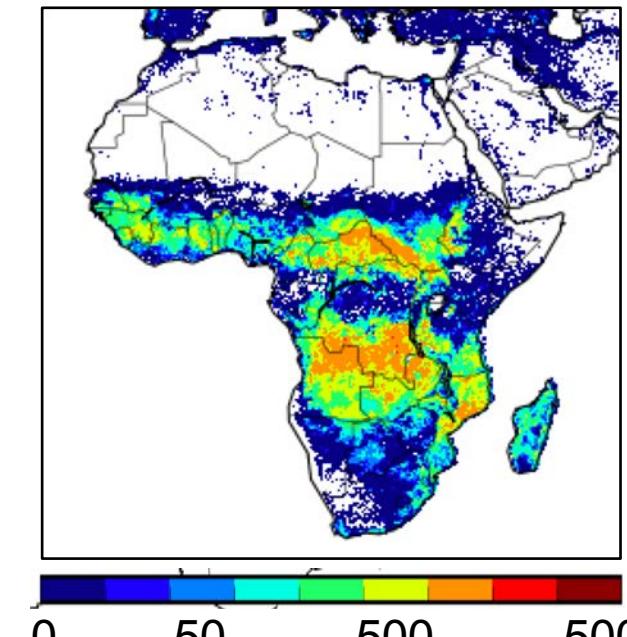
Charcoal Activities and Pollutant Emissions

Total and Relative Emissions



Comparison to Open Fires

Inventory (GFED4) carbon emissions
[g C m⁻² year⁻¹]



[\[https://daac.ornl.gov/\]](https://daac.ornl.gov/)

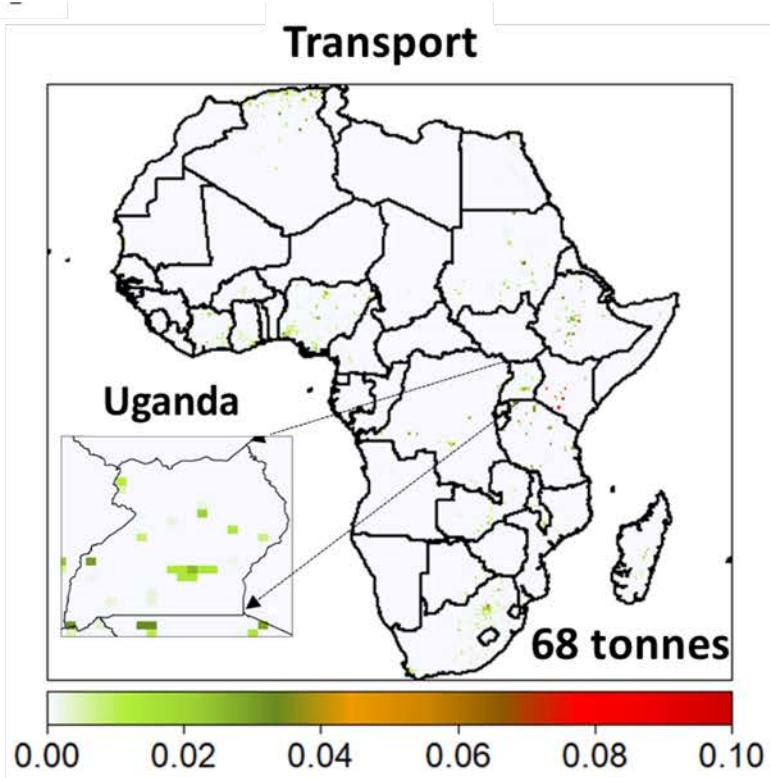
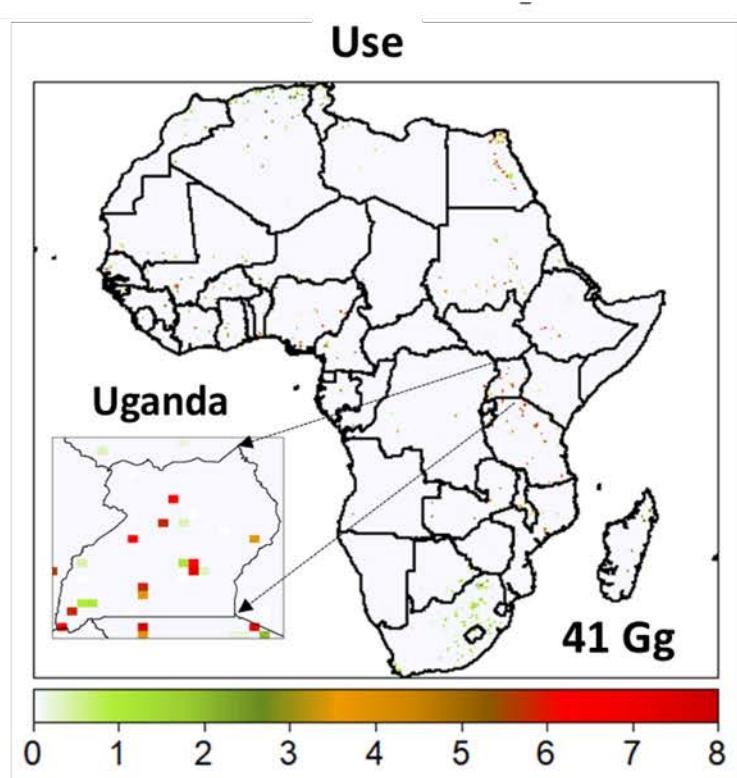
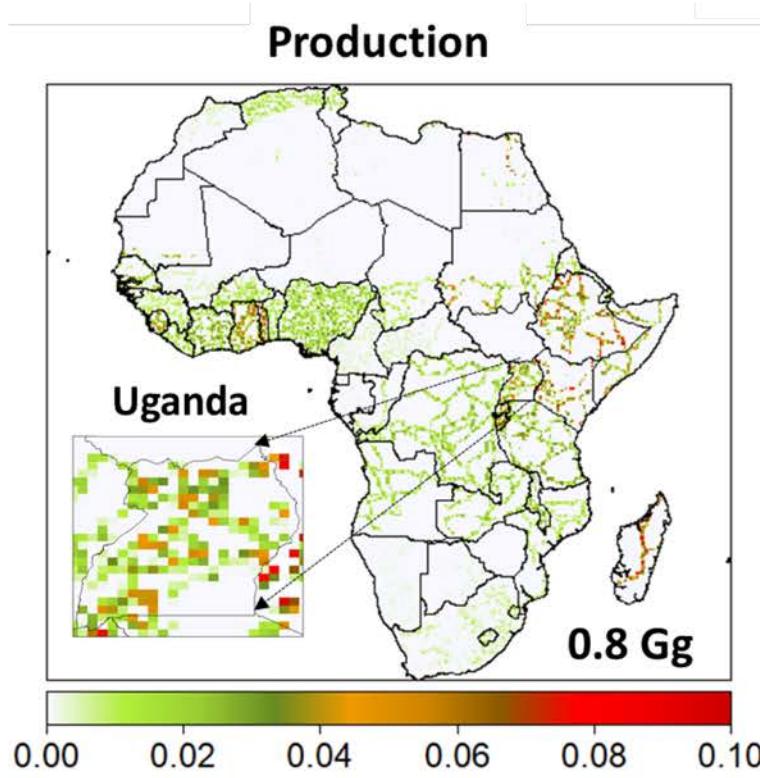
CH₄: 4.6 Tg
BC: 0.81 Tg C
CO: 136 Tg
OC: 5.6 Tg C

Spatial Distribution of Emissions

Apply reported emission factors of air pollutants to mapped activities



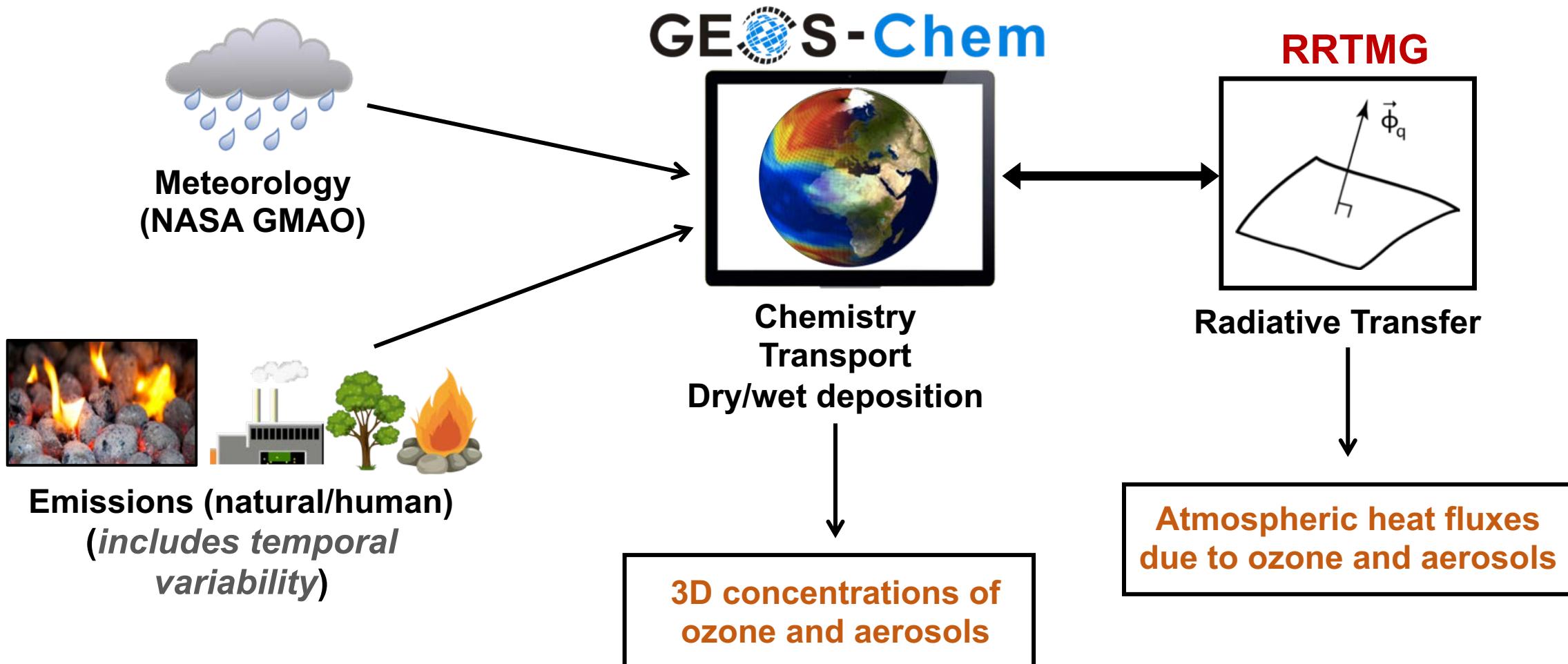
Black carbon emissions at $0.1^\circ \times 0.1^\circ$ grid for 2014 [tonnes per year]



Emissions on a trajectory to double by 2030

Quantify the Contribution to Air Pollution and Climate Change

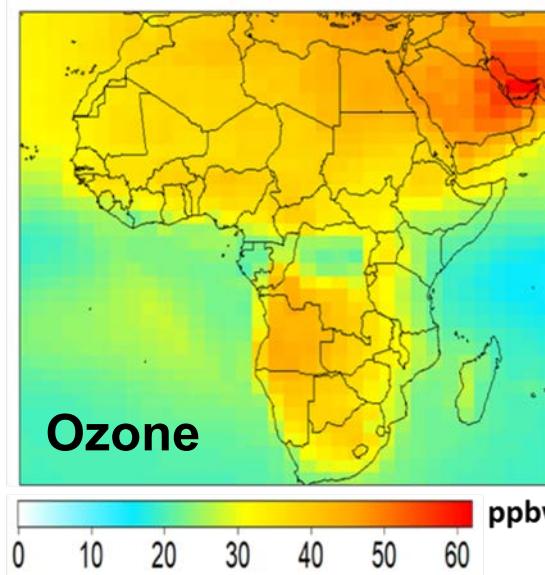
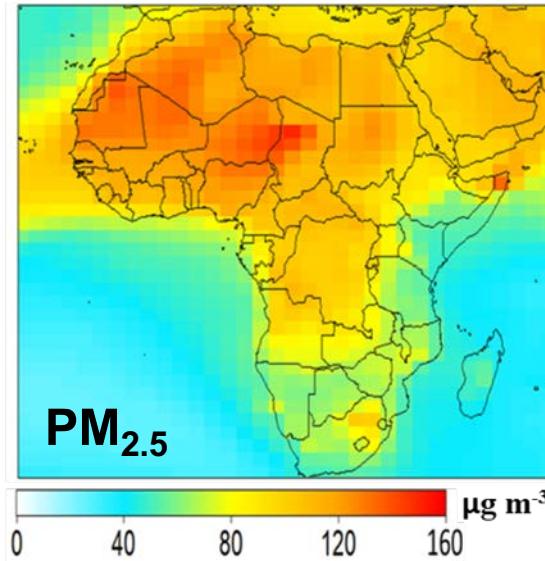
Coupled 3D atmospheric chemistry and radiative transfer models



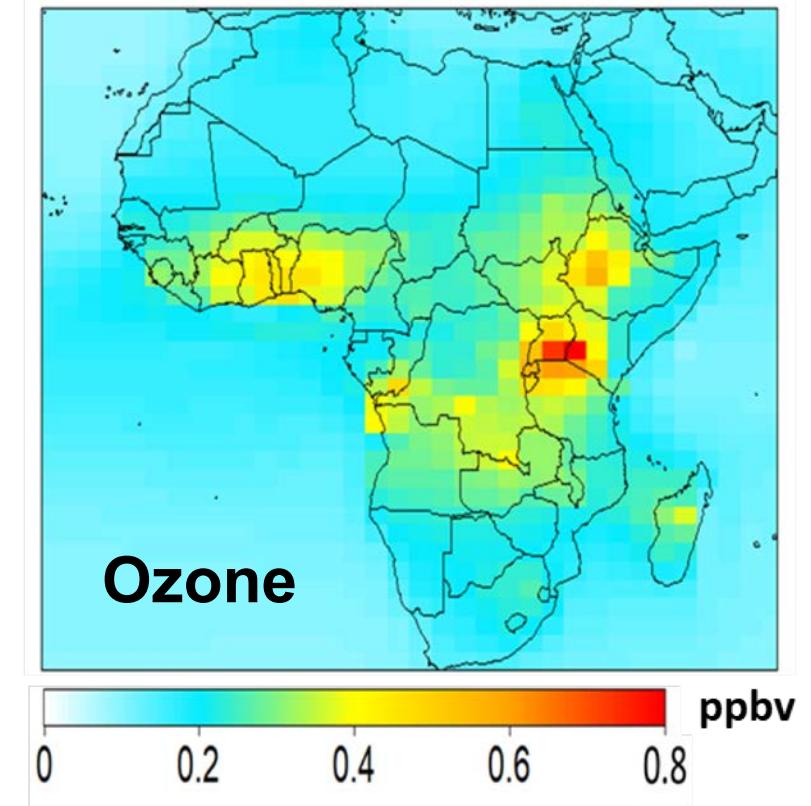
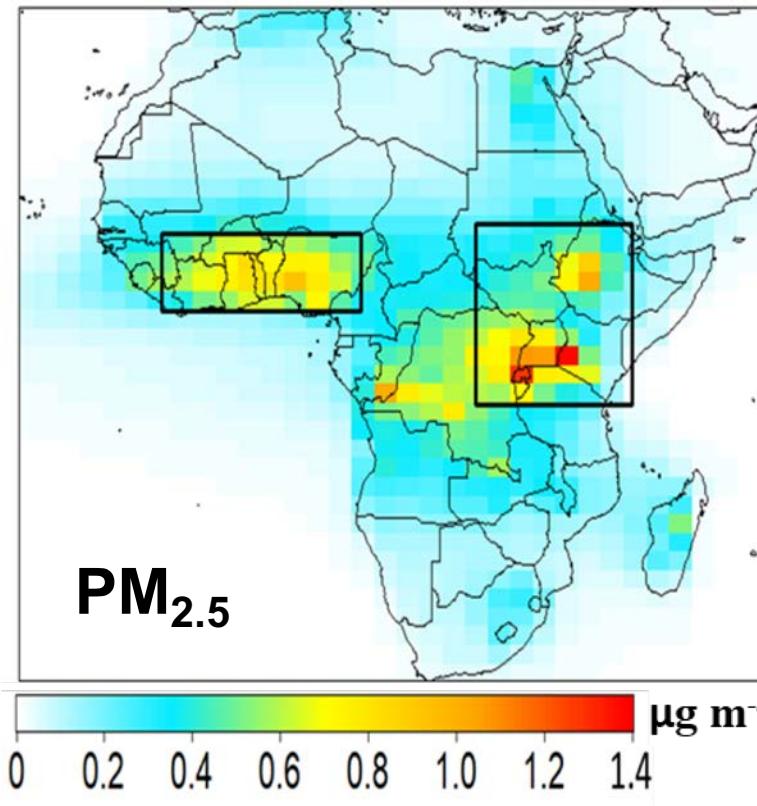
To find out more about GEOS-Chem: <http://acmg.seas.harvard.edu/geos/index.html>

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



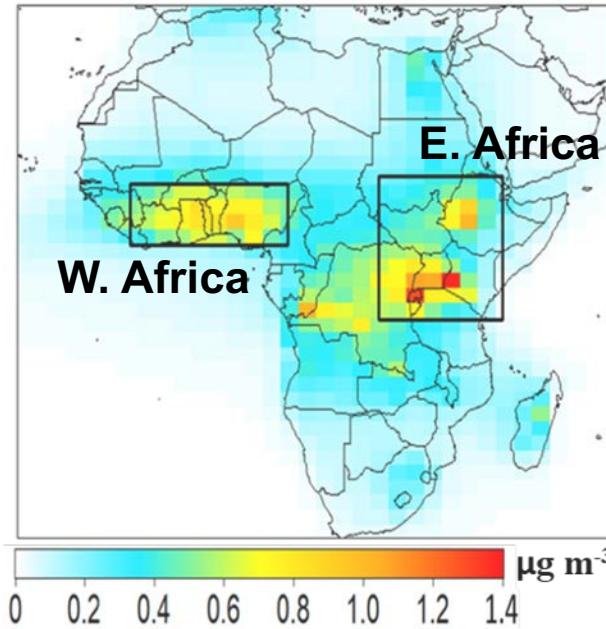
Peaks in urban areas in East, West and Central Africa, as expected from spatial distribution of emissions

PM_{2.5} > 0.8 $\mu\text{g m}^{-3}$ 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}

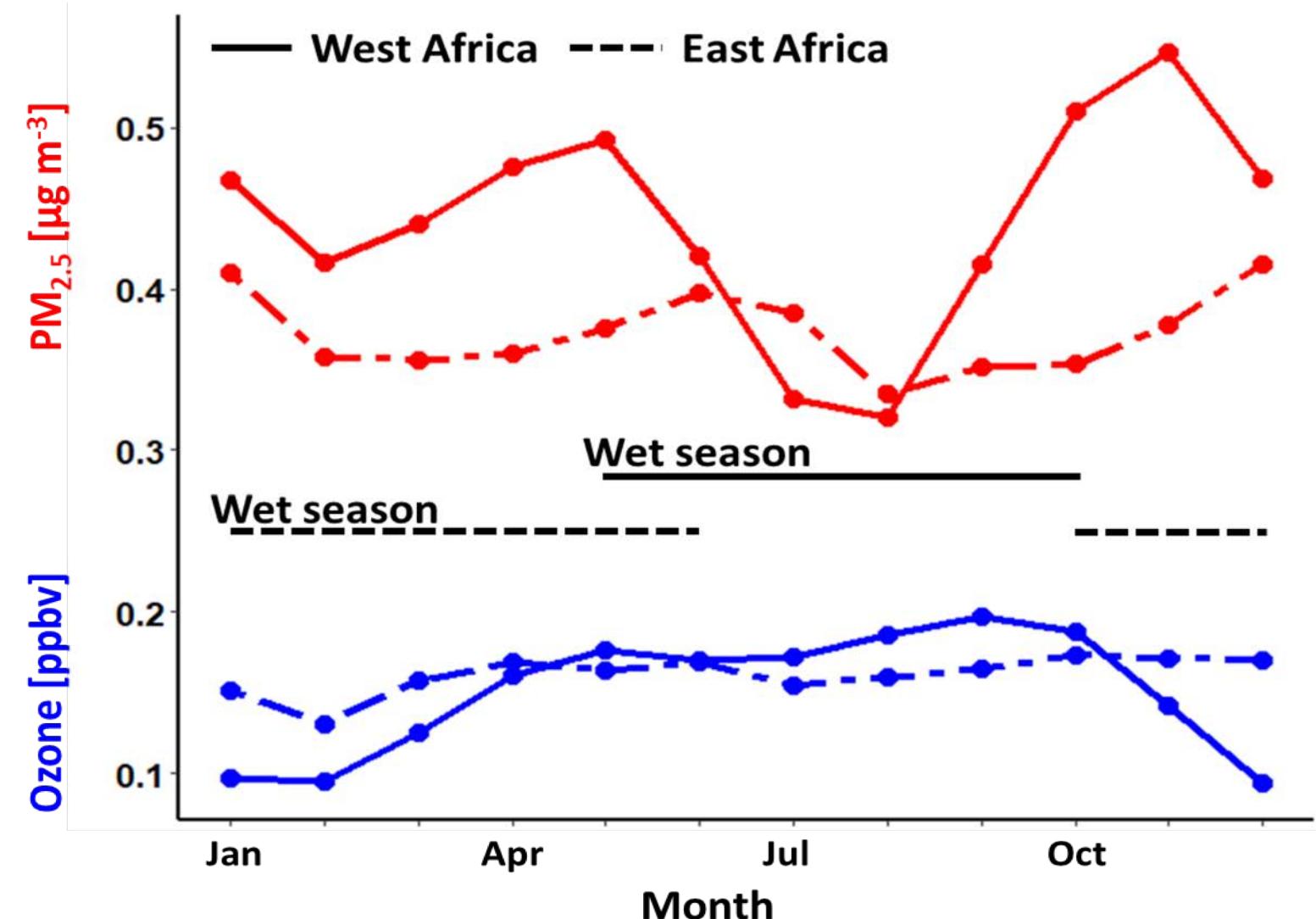


Seasonality most pronounced in West Africa

PM_{2.5} seasonality due to monsoon and Harmattan winds

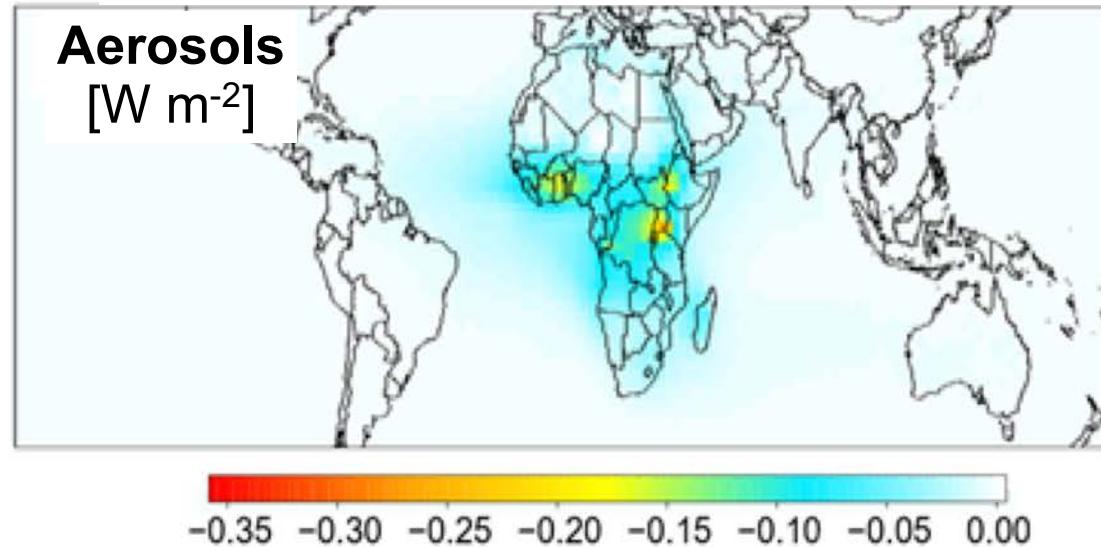
Ozone formation sensitive to NO_x in wet season

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



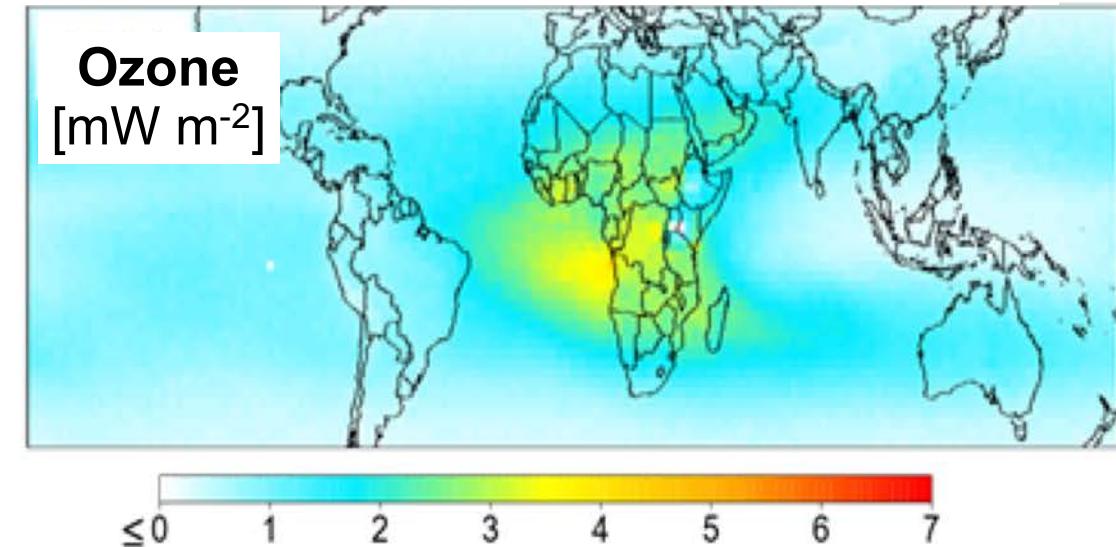
Shortwave cooling

Due mostly to scattering by organic aerosols

Localized effect, peaking in dense urban areas

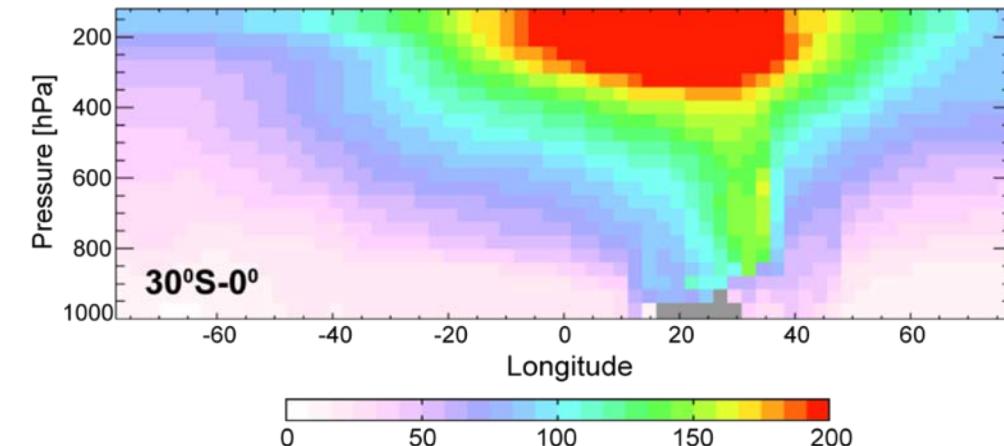
Continent mean: **-30 mW m⁻²**

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

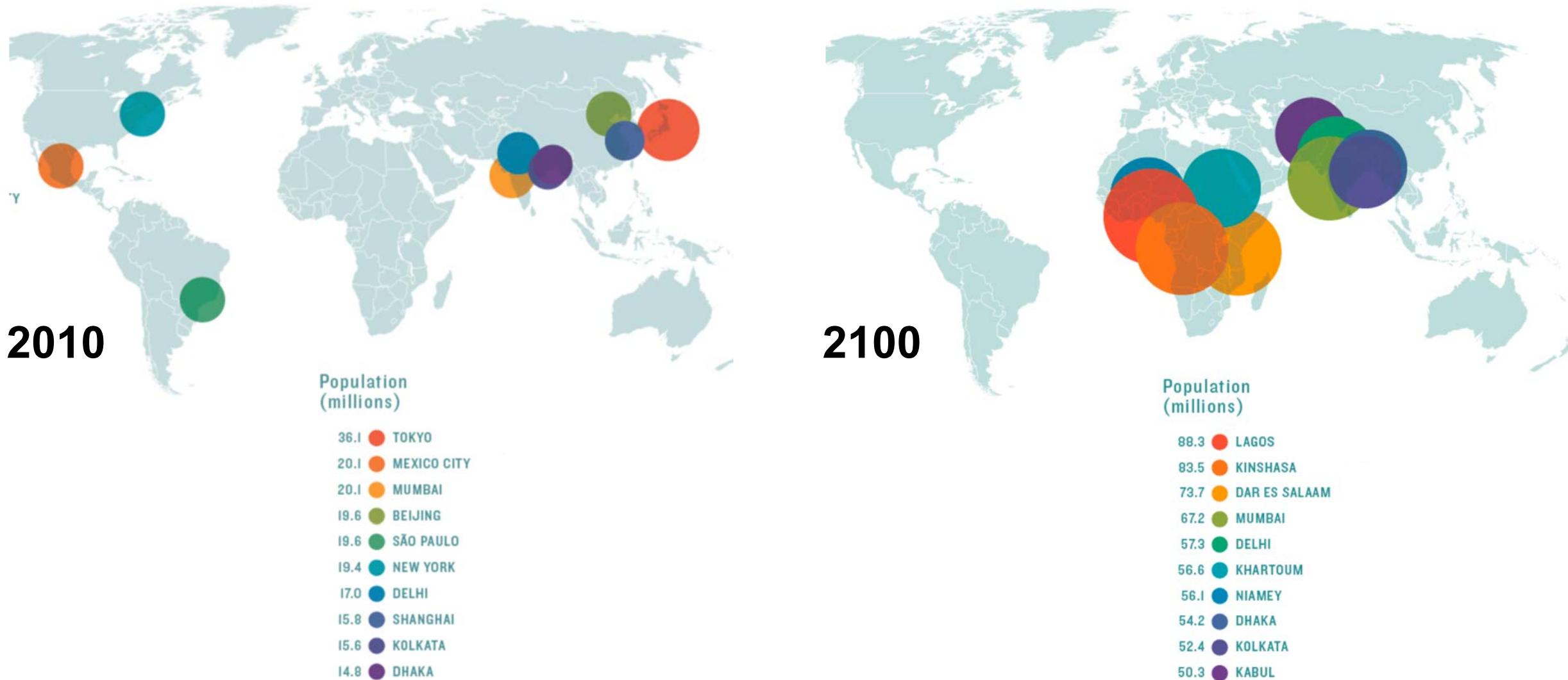


Image source: <http://edge.ensia.com/here-come-the-megacities/>

Data source: <https://journals.sagepub.com/doi/pdf/10.1177/0956247816663557>