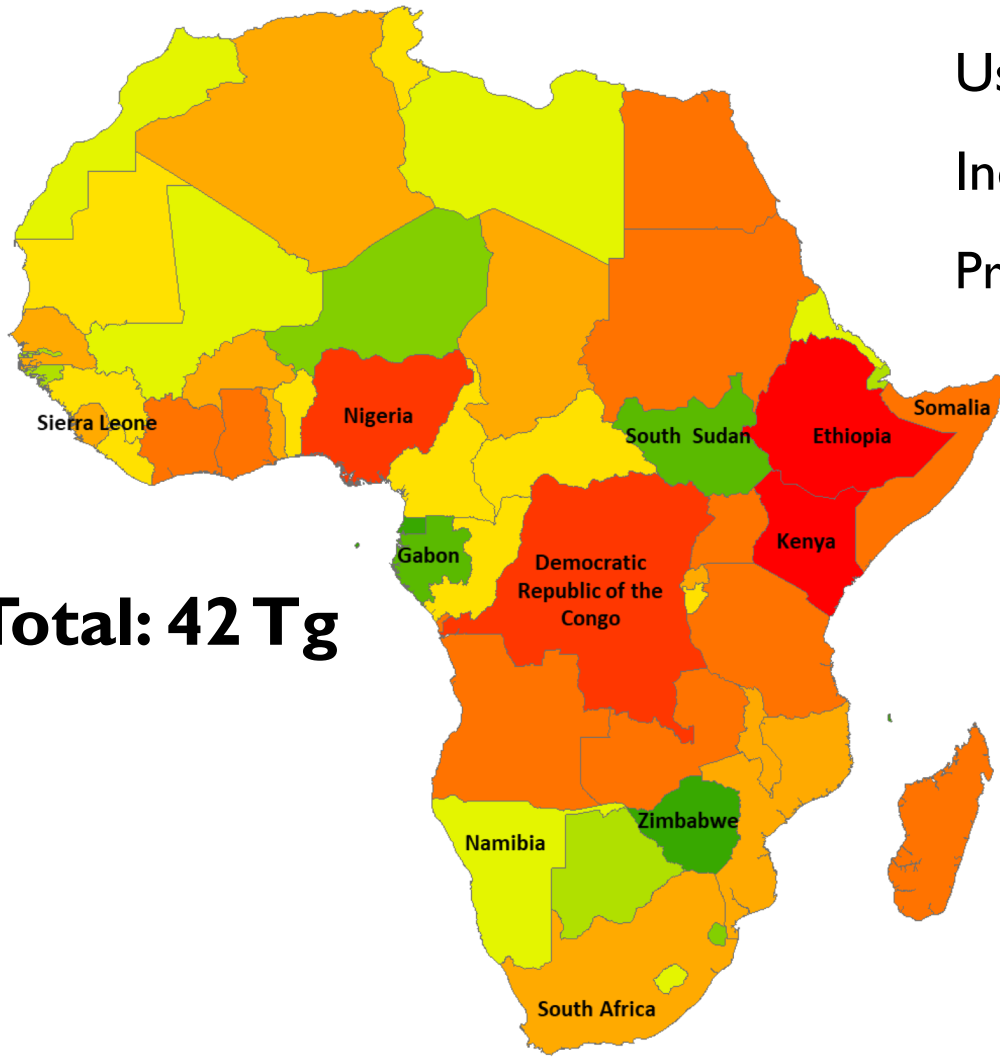
Air Quality and Climate Forcing of the Charcoal Industry in Africa

Charcoal Production in 2014



Total: 42 Tg

Used by **>80%** of urban population

Increasing by **7% per year**

Projected to **double by 2030**

[Gg per year]

- 0 - 10
- 11 - 30
- 31 - 50
- 51 - 100
- 101 - 200
- 201 - 400
- 401 - 1000
- 1001 - 2000
- 2001 - 4000
- > 4000

[Bockarie et al., ES&T, in review]

Charcoal Supply Chain Activities Mapping

Production

Kilns combustion efficiency is 9-30%
CO, NMVOCs, OC, CH_4

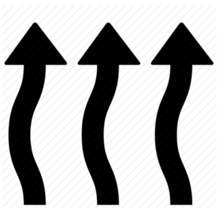
Transport

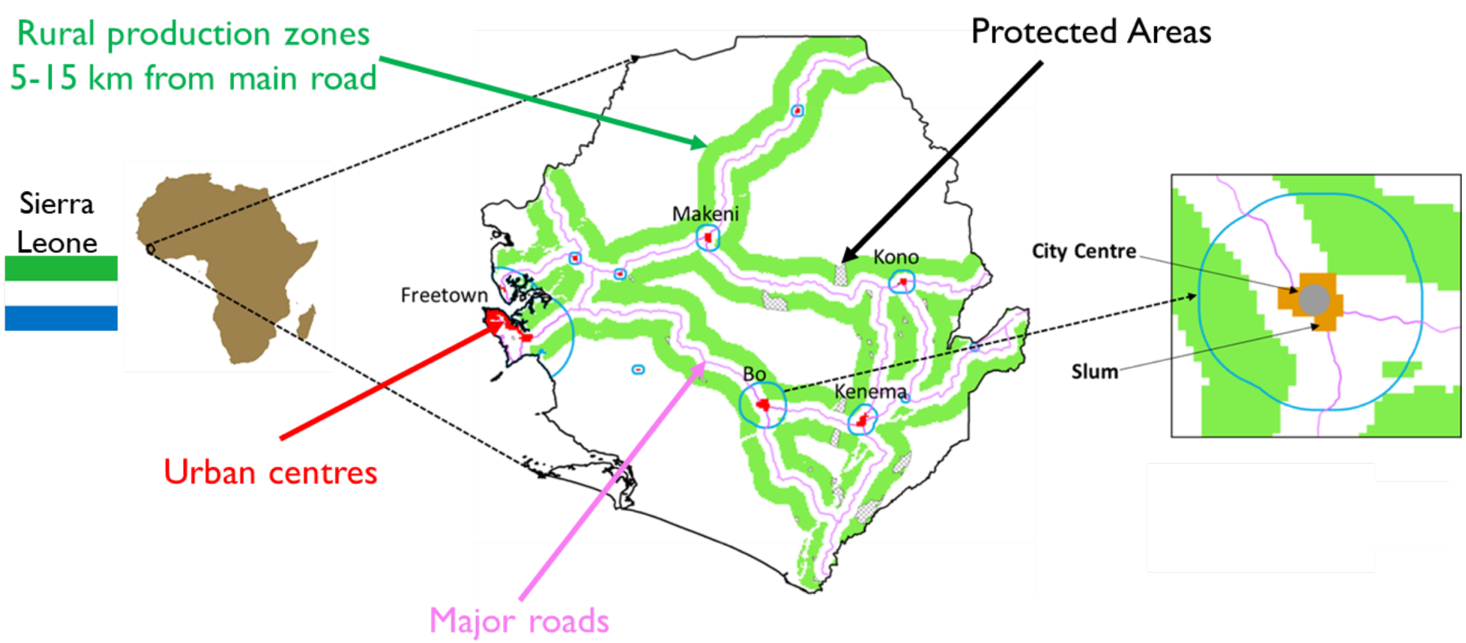
Unregulated and outdated diesel trucks: SO_2, BC

Use

Charcoal: NO_x and BC
Plastic burning: HCl

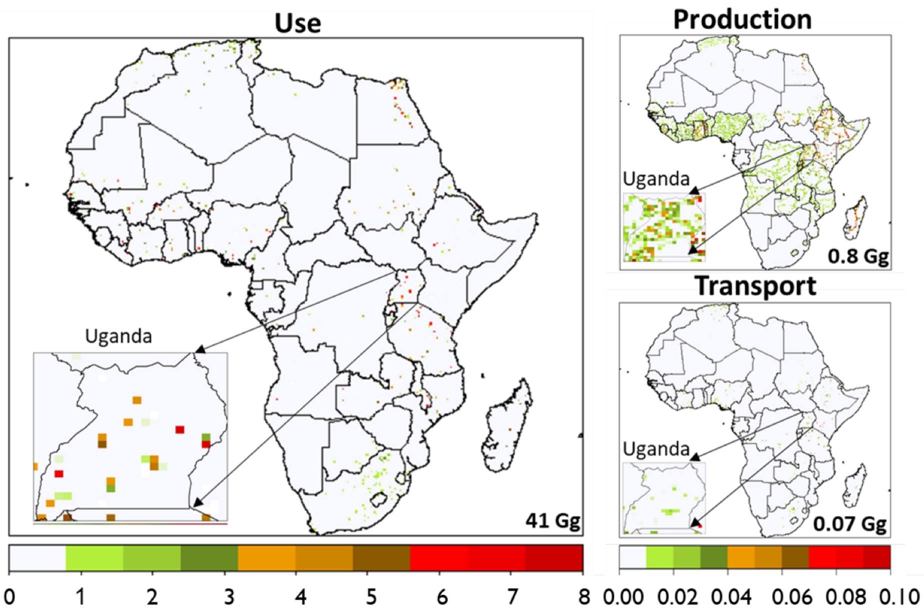
Emissions



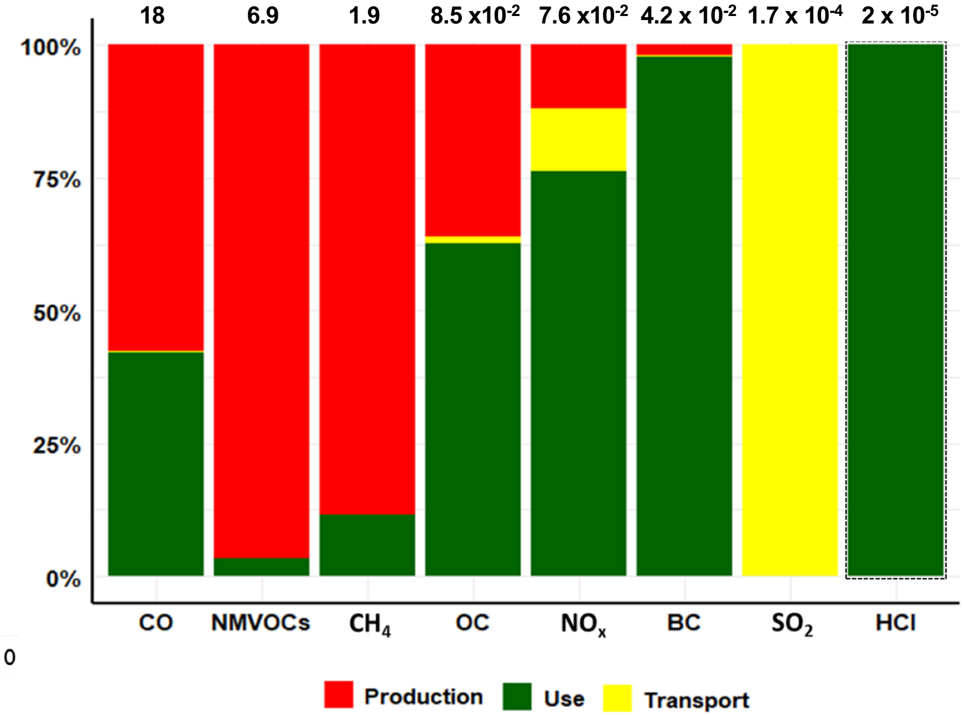


Charcoal Activities and Pollutant Emissions

Black carbon emissions at 0.1° x 0.1° [tonnes per year]



Total and Relative Emissions [Tg]



208 Tg wood used to produce charcoal

Most BC from use (higher efficiency)

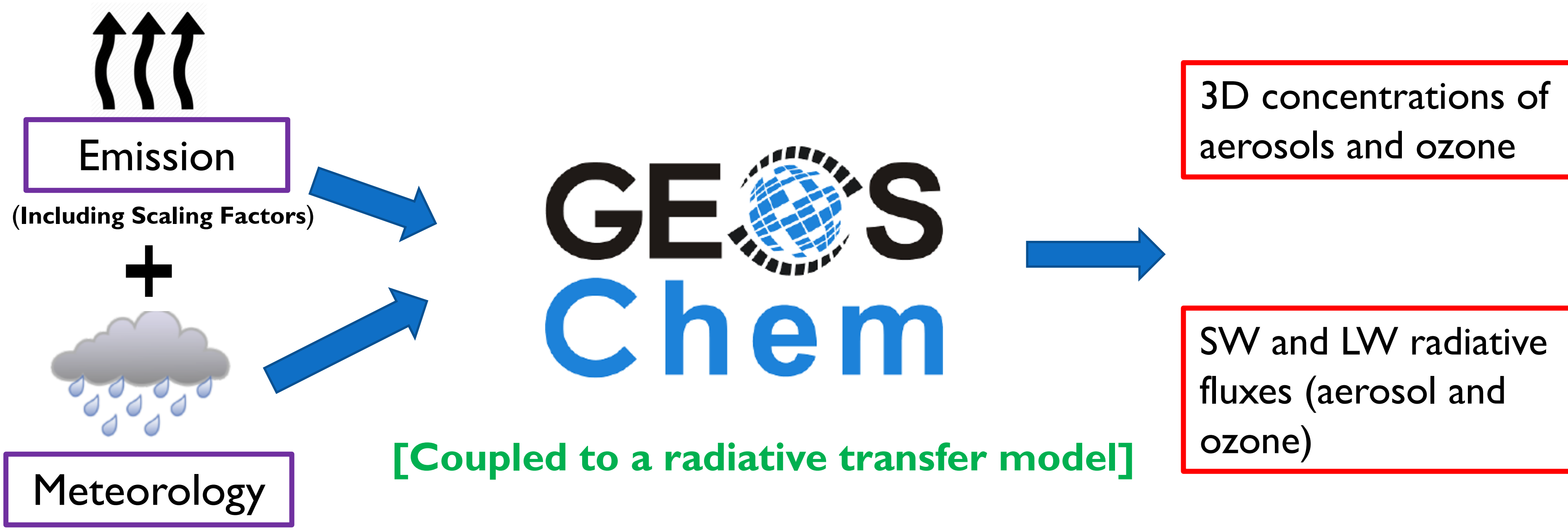
Trucks BC is small <2%, but our emission factors are conservative

Production and use are largest contributors

Emission factors are a large source of uncertainty

Emissions on a trajectory to double by 2030

Estimating Air Quality and Climate Forcing of Charcoal

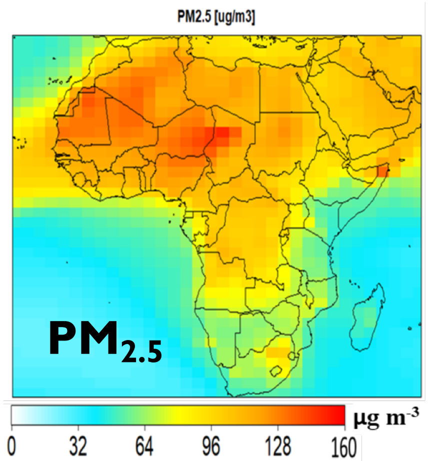


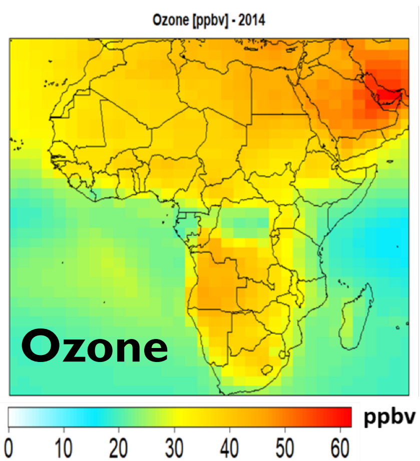
3D Chemical transport model driven by reanalysis meteorology
Grid Resolution: $2^{\circ} \times 2.5^{\circ}$ (~200 - 250 km)

We use GEOS-Chem coupled to RRTMG to determine the air quality and climate effect of charcoal in Africa

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

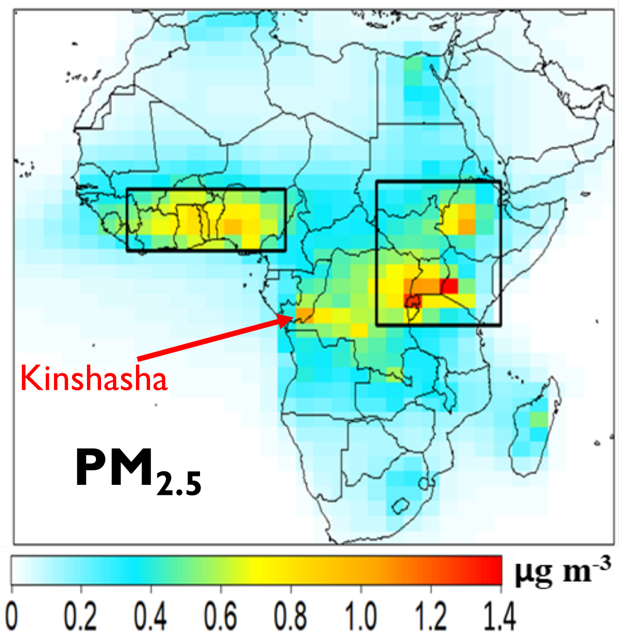
$PM_{2.5}$ and Ozone from all sources

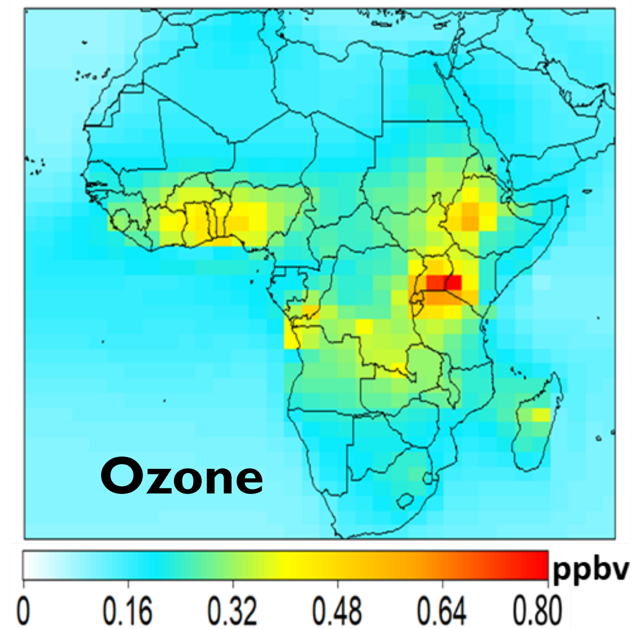




Most $PM_{2.5}$ is from windblown dust. Non-natural $PM_{2.5}$ and ozone are from open fires in East & West Africa and coal burning from South Africa

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



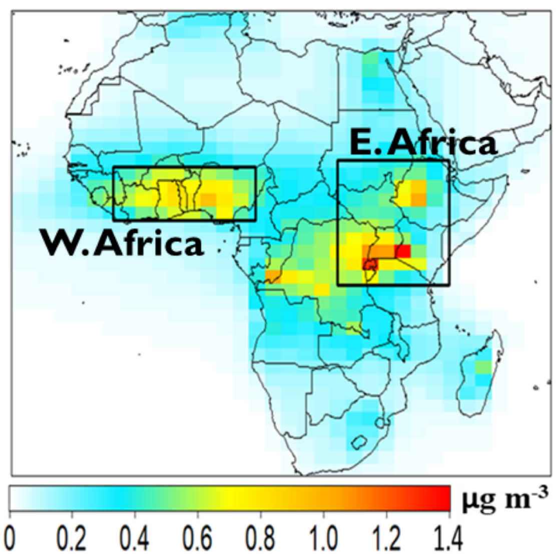


Largest enhancements are in urban centres in East and West Africa, and in Kinshasa, DRC

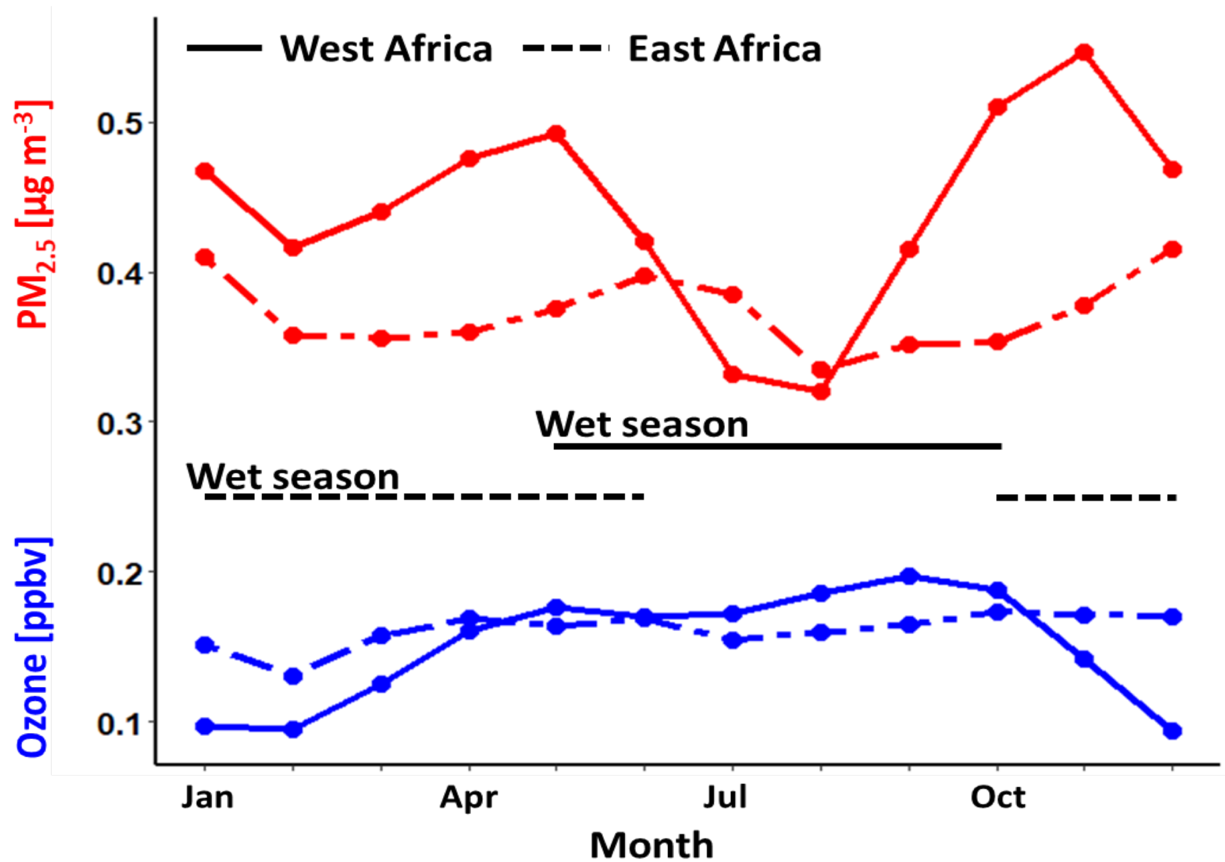
- $PM_{2.5}$ enhancement > 0.8 µg m^{-3} in East Africa may have serious health implications
- Surface ozone increase is small (at most 0.8 ppbv)

Seasonality of Surface Concentrations of Air Pollutants

Regional hotspots of charcoal industry $PM_{2.5}$



Monthly mean charcoal industry $PM_{2.5}$ and ozone from charcoal for regional hotspots



Seasonality most pronounced in West Africa for ozone and $PM_{2.5}$.

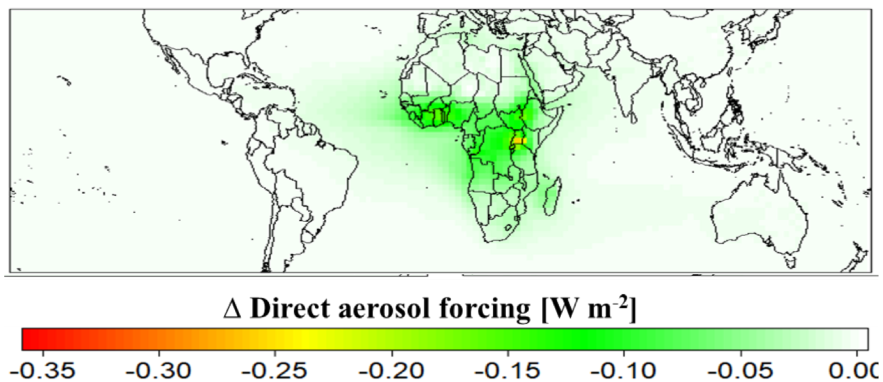
$PM_{2.5}$ seasonality due to monsoon and Harmattan winds.

Ozone formation sensitive to NO_x-limited wet season (no NO_x from open fires)

Top-of-Atmosphere Direct All-Sky Radiative Forcing

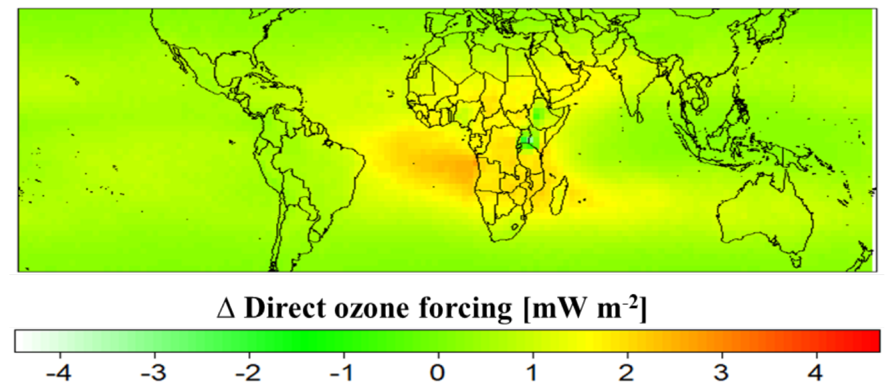
Aerosols

2014



Ozone

2014



Shortwave cooling

Mostly due to scattering by OA

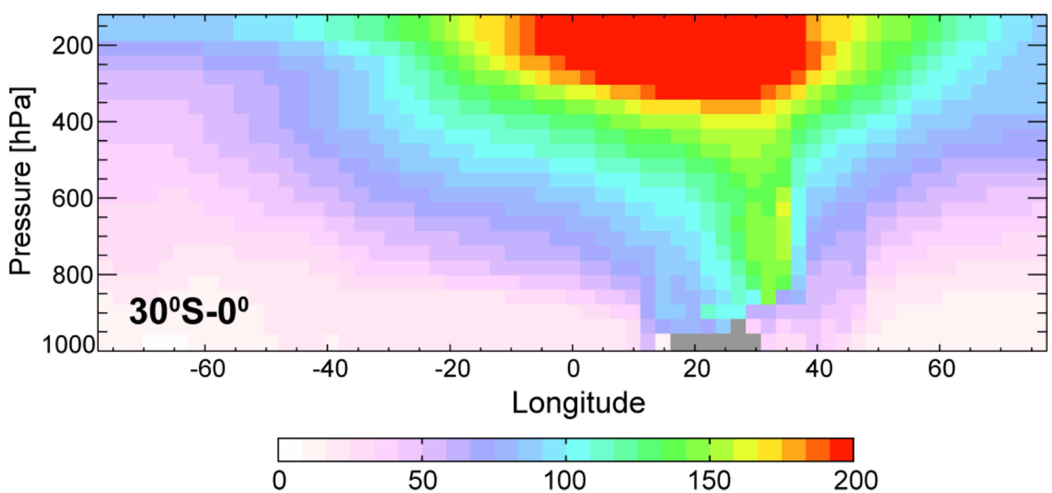
Effect is local and peaks in dense urban areas

Continent mean of -30 mW m^{-2} is a greater response than studies that perturb open fire emissions by 10%

Long- and short-wave warming

Mostly due to ozone in the upper troposphere:

Vertical distribution of annual mean tropospheric ozone averaged across the southern hemisphere



Future Impact if Current Behaviour Persists

Top 10 megacities in 2010 and 2100

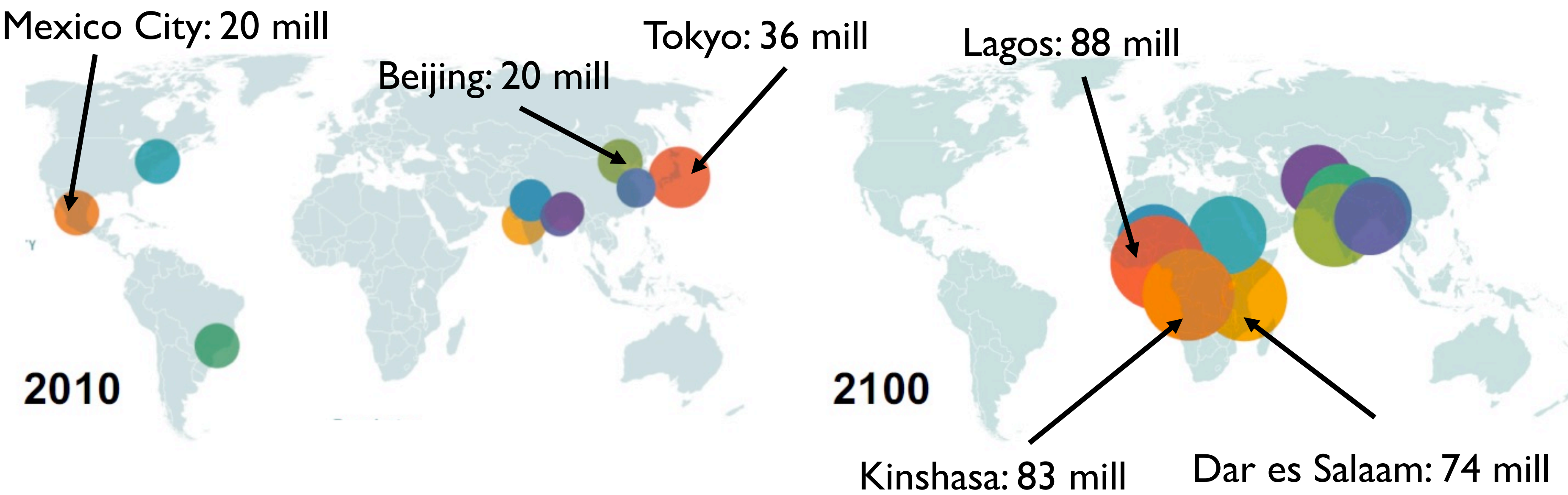


Image source: http://edge.ensia.com/here-come-the-megacities/
Data source: https://journals.sagepub.com/doi/pdf/10.1177/0956247816663557

The impact of charcoal on the environment will worsen by 2100,
as the urban population in Africa will increase
from 50% today to 70% by 2100