Air Quality and Climate Impact of the Charcoal Industry in Africa

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Multiplatform Approach to Solve Societal Issues

CHAMBER

GEOS Chem

3D ATMOSPHERIC CHEMISTRY MODEL

SATELLITES

IN SITU

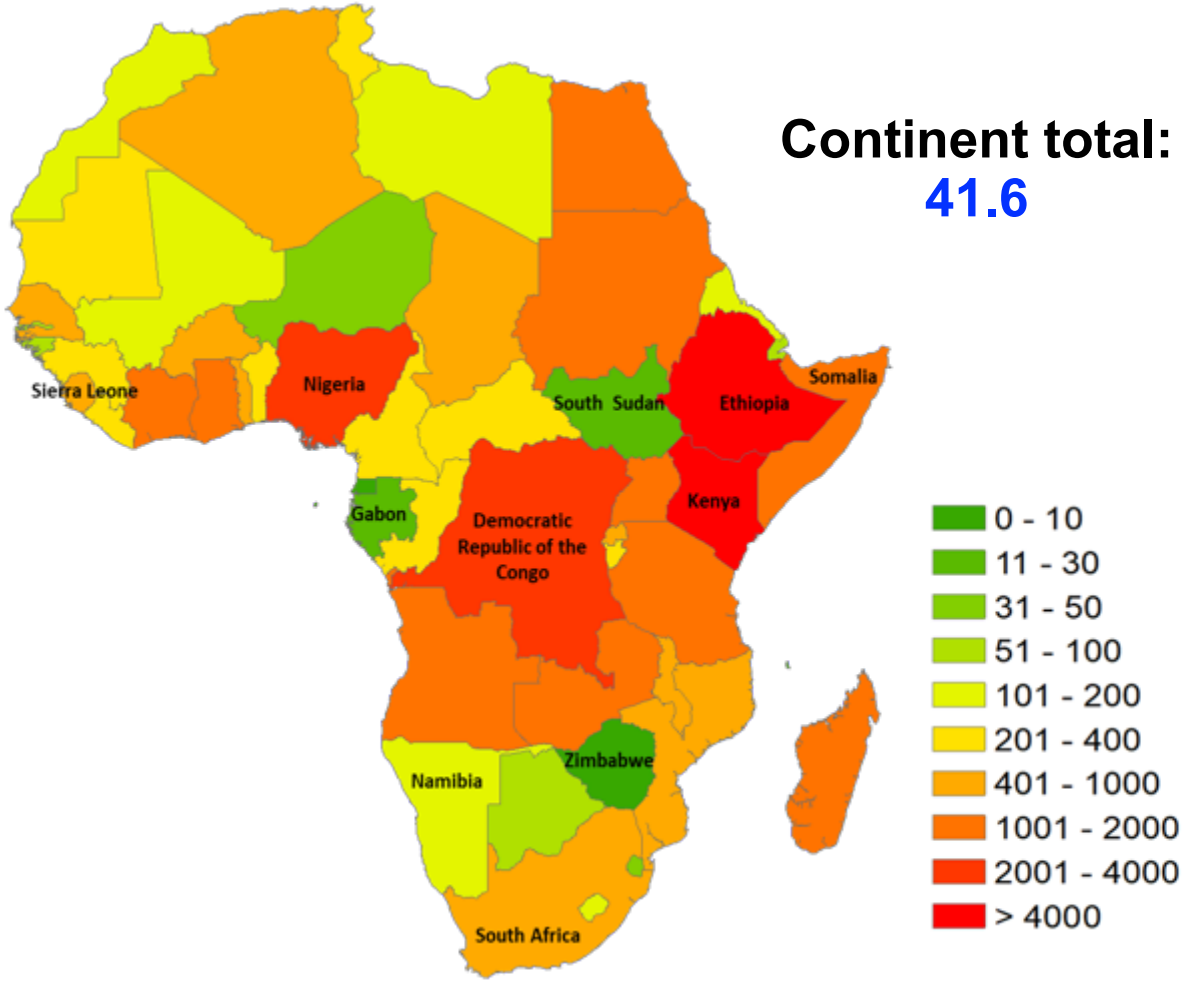
My group uses and develops state-of-science observations and tools to inform policy.

Research Group Members

Alfred (PhD), me, Alok (postdoc), Chloe (visiting UG), Gongda (PhD), Karn (PhD), Nana (PhD), Rob (postdoc)

The Burgeoning Charcoal Industry in Africa

Charcoal Production in 2014 [million tonnes]

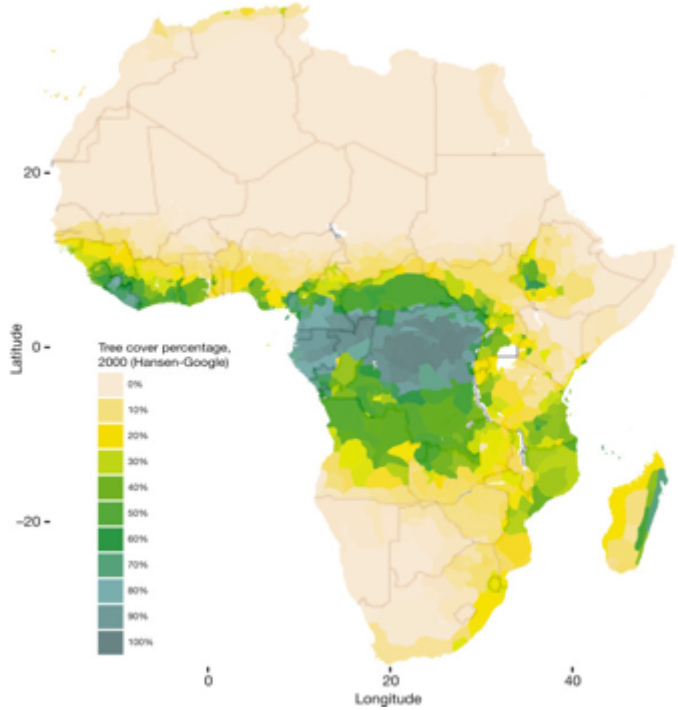


Continent total:
41.6

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

[Bockarie et al., 2020]

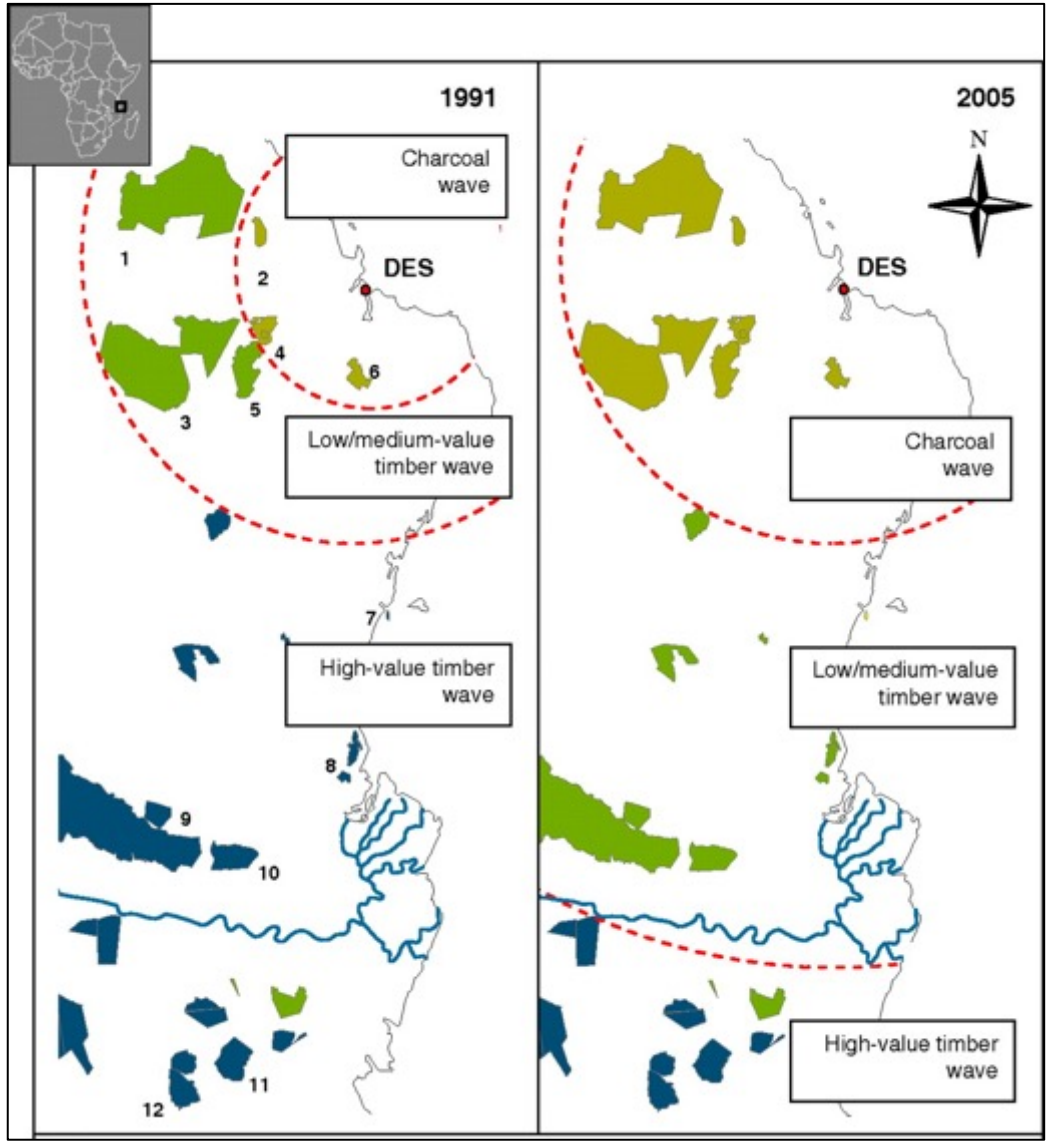
Percent Tree Cover in Africa



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

Average annual increase:
7 % per year
(driven by urbanization)

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/]

WHO guideline: 10 μg m^{-3}

Mapping Charcoal Industry Activities (Fuel Use)

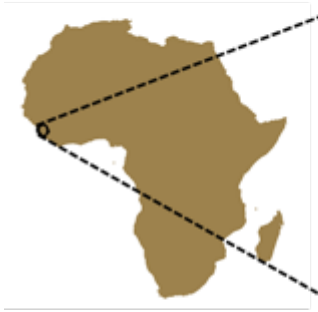
Produce

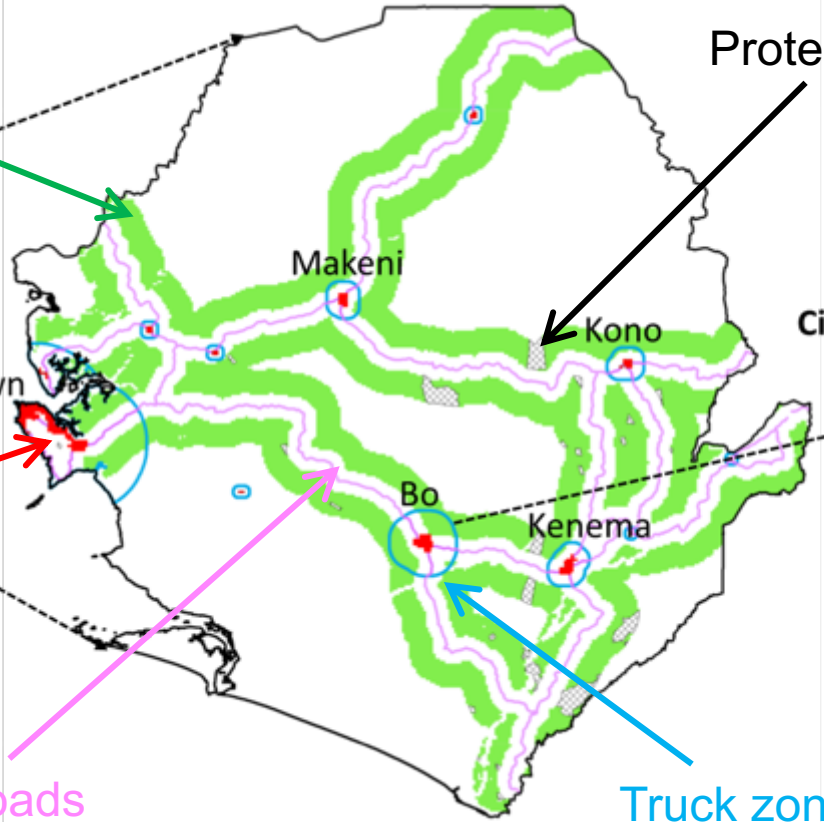
Transport

Use

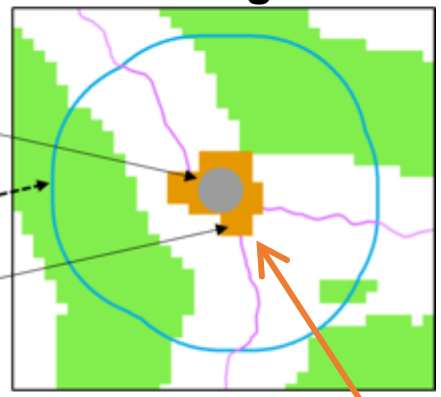
Rural production zones

Protected areas





Bo city centre and surrounding slums



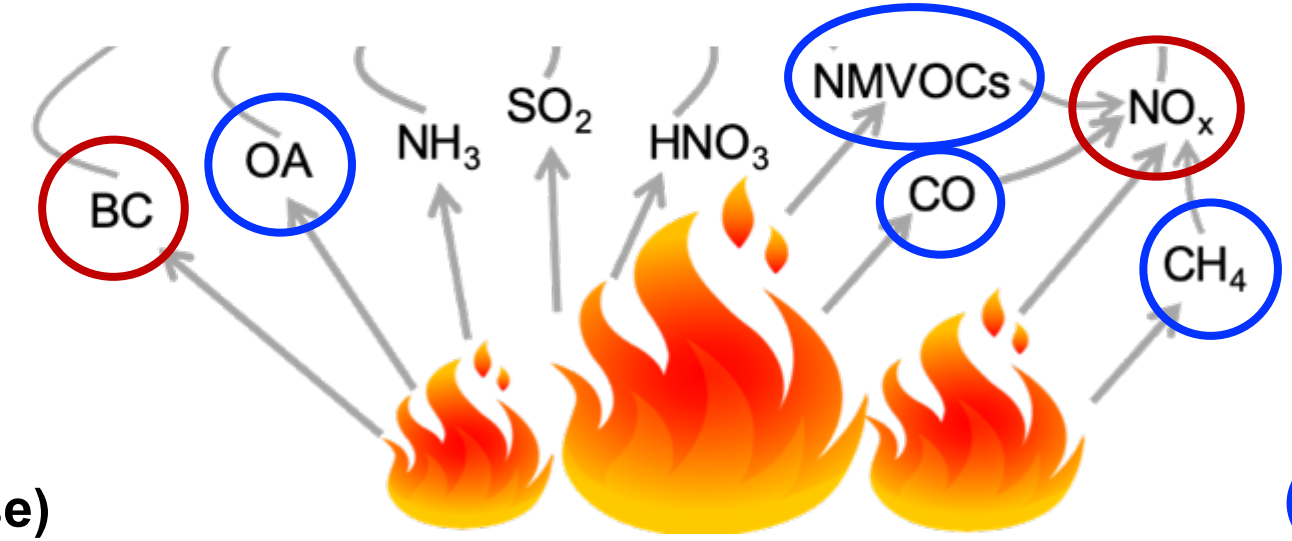
Urban centres

Major roads

Truck zones

Plastic burning to initiate combustion limited to slums

The Pollutants Emitted from Charcoal Production, Use and Transport



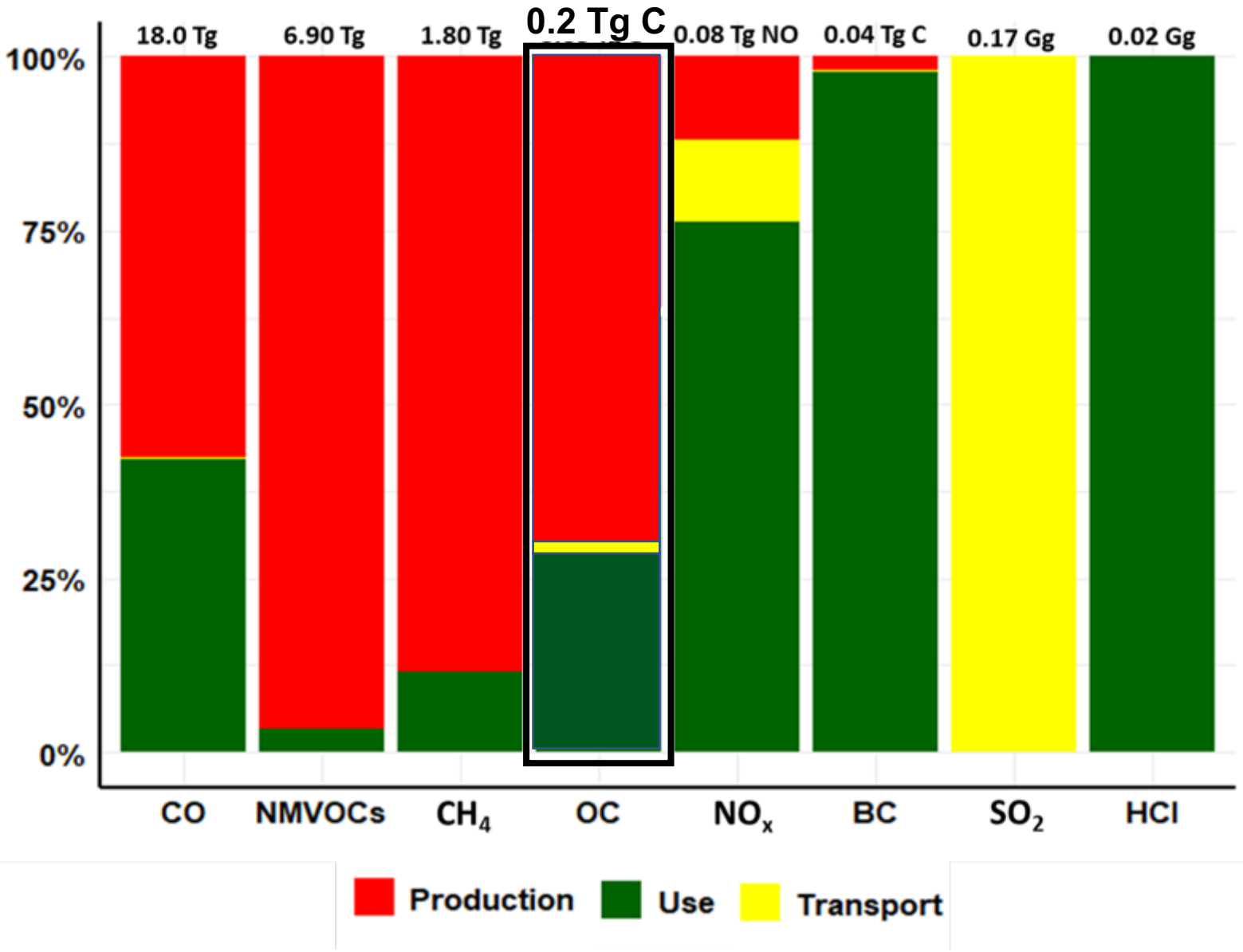
Efficient (use)

Efficient (transport)

Inefficient (production)

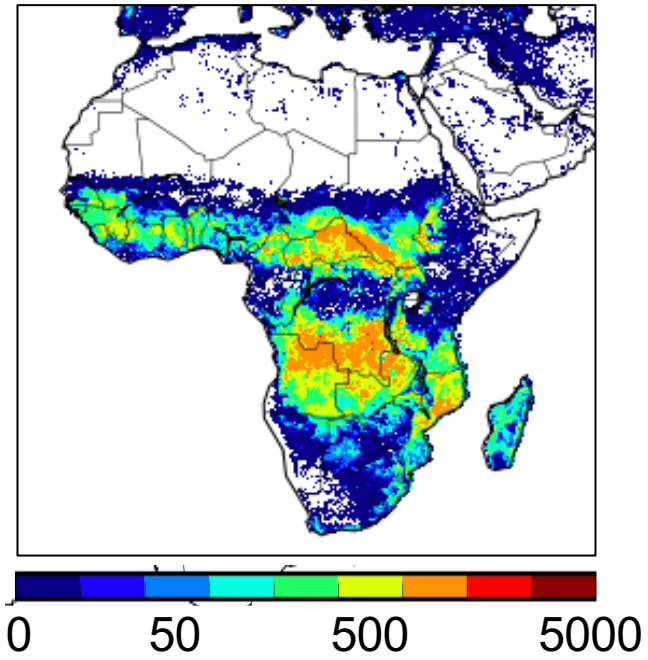
Charcoal Activities and Pollutant Emissions

Total and Relative Emissions



Comparison to Open Fires

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



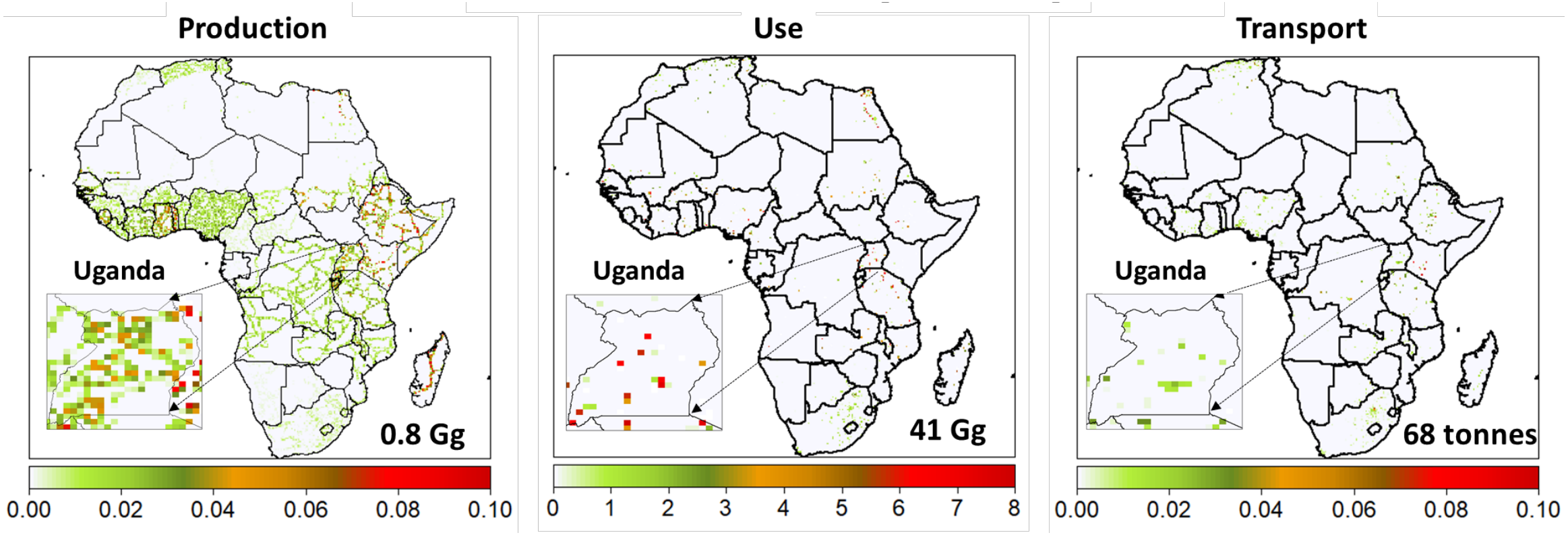
[https://daac.ornl.gov/]

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

Spatial Distribution of Emissions

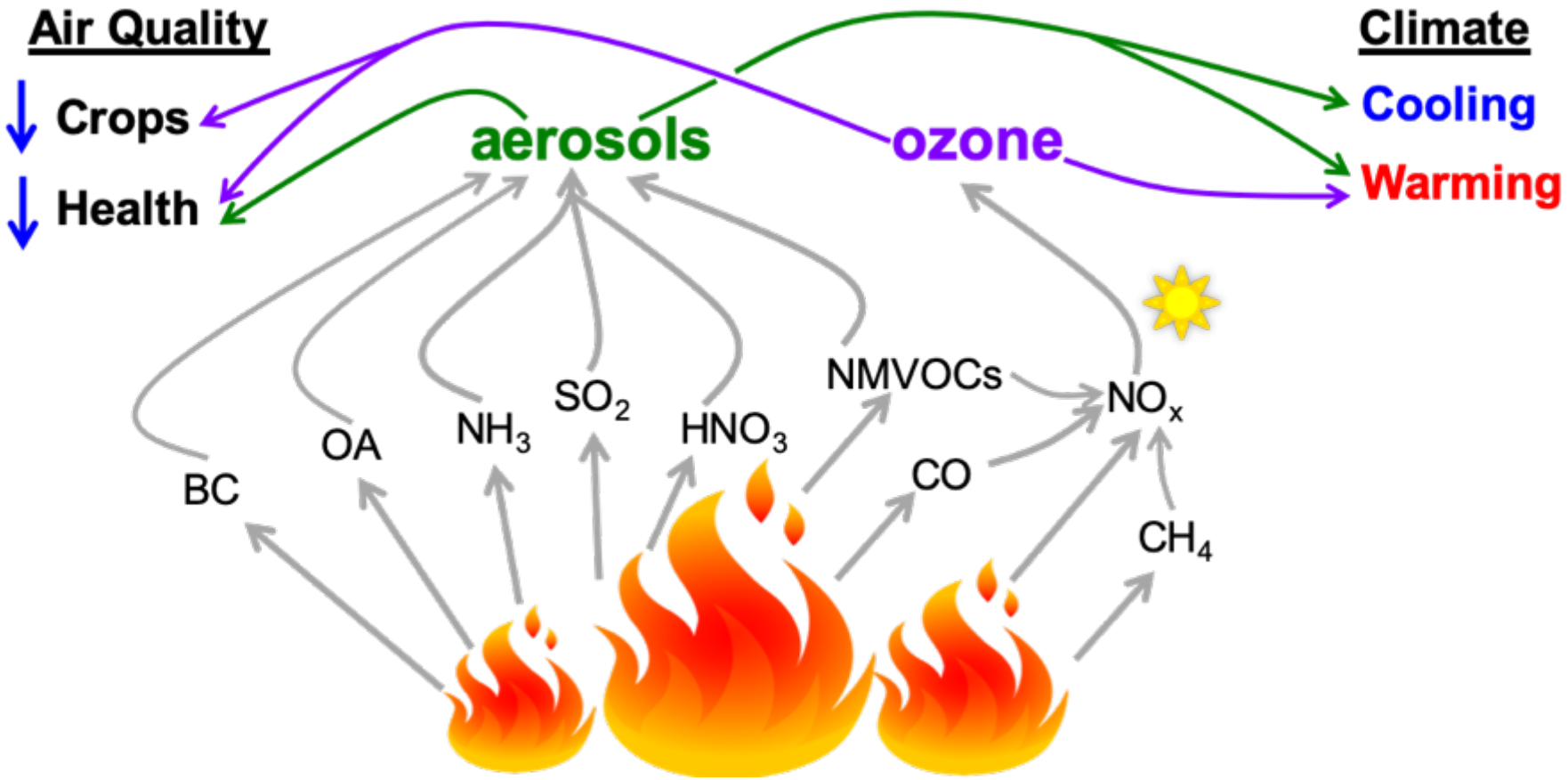
Apply reported emission factors of air pollutants to mapped activities

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



Emissions on a trajectory to double by 2030

Air Pollutants and Climate Forcers

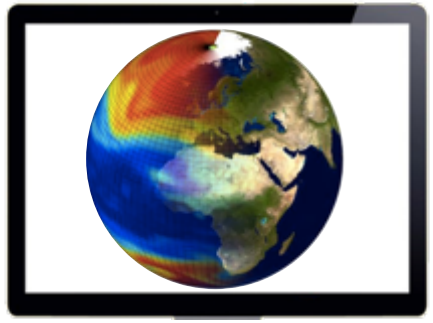


Quantify Impact on Air Quality and Climate

Coupled 3D atmospheric chemistry and radiative transfer models

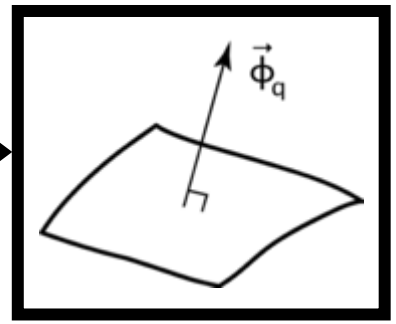
GEOS-Chem

Meteorology
(NASA GMAO)



Chemistry
Transport
Dry/wet deposition

RRTMG



Radiative Transfer Model

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

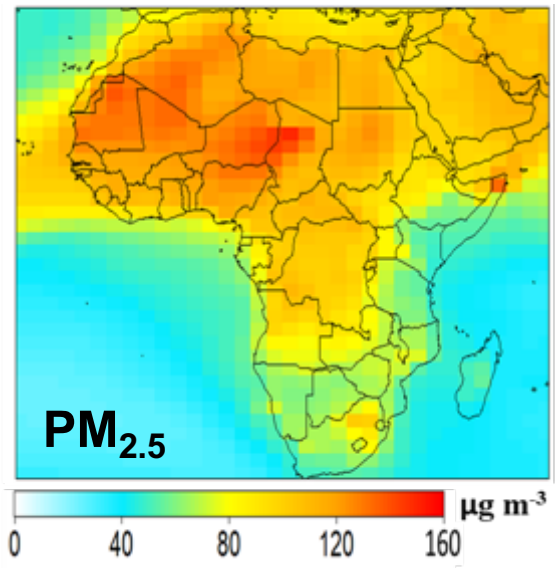
Air quality impact
(Surface concentrations of ozone and $PM_{2.5}$)

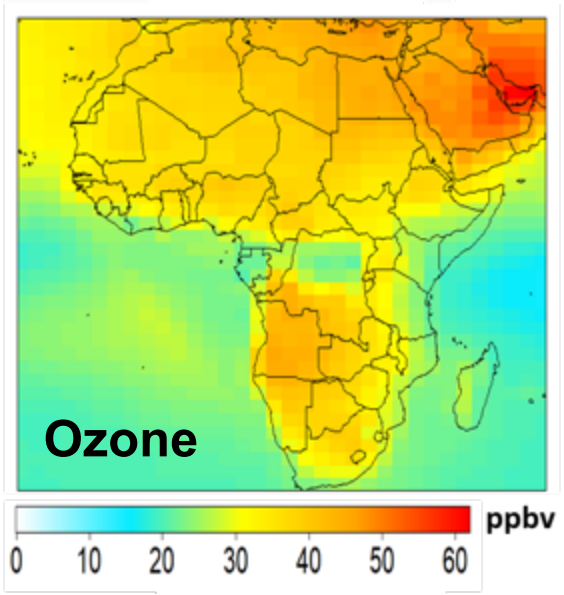
Climate impact
(Atmospheric heat fluxes due to ozone and aerosols)

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

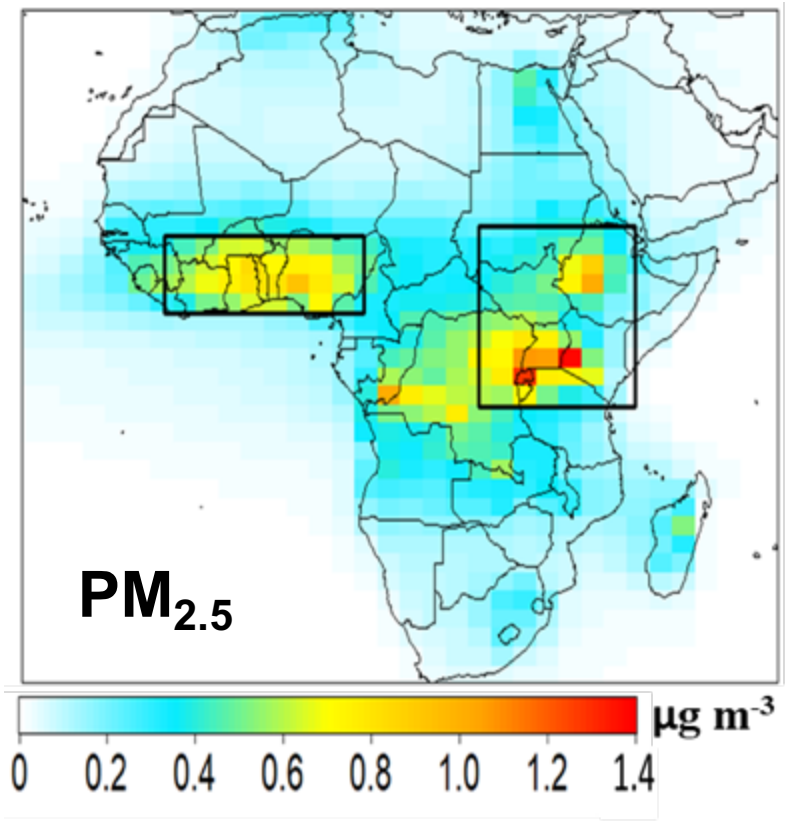
Total and Charcoal Industry Surface $PM_{2.5}$ and Ozone

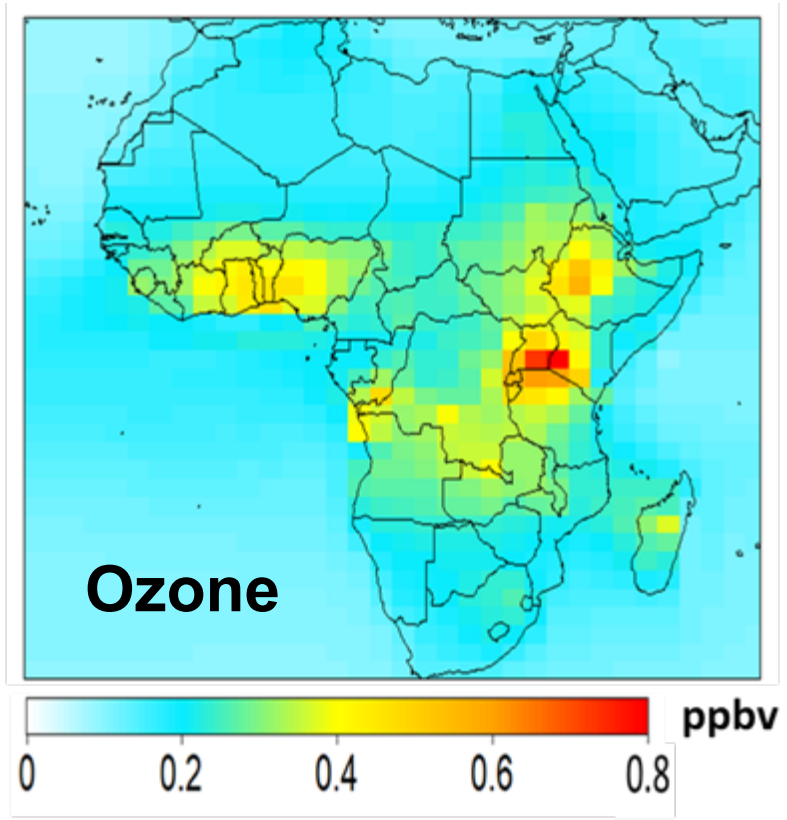
$PM_{2.5}$ and Ozone from All Sources





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





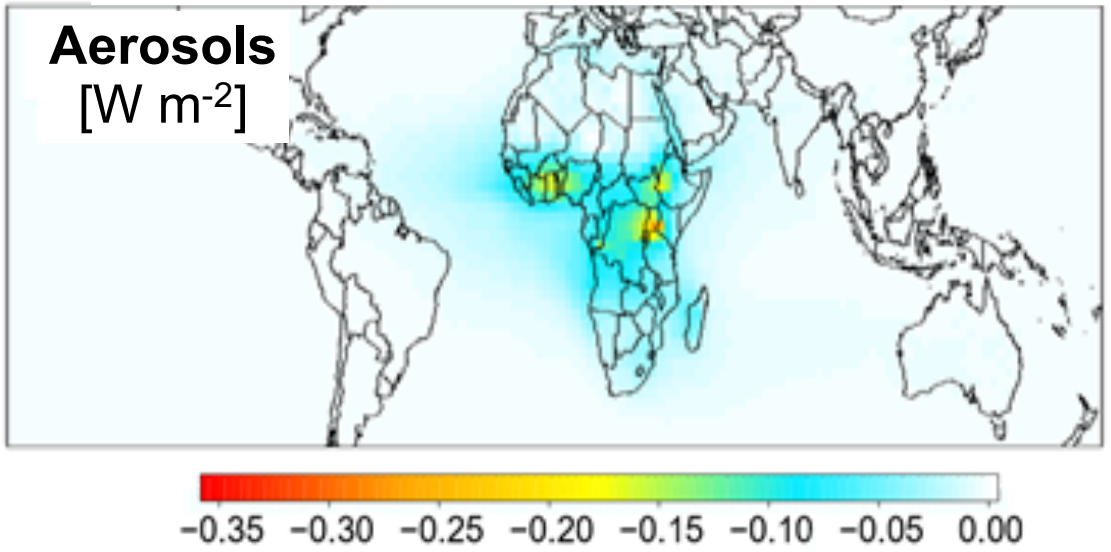
Peaks in urban areas in East, West and Central Africa, as expected from spatial distribution of emissions

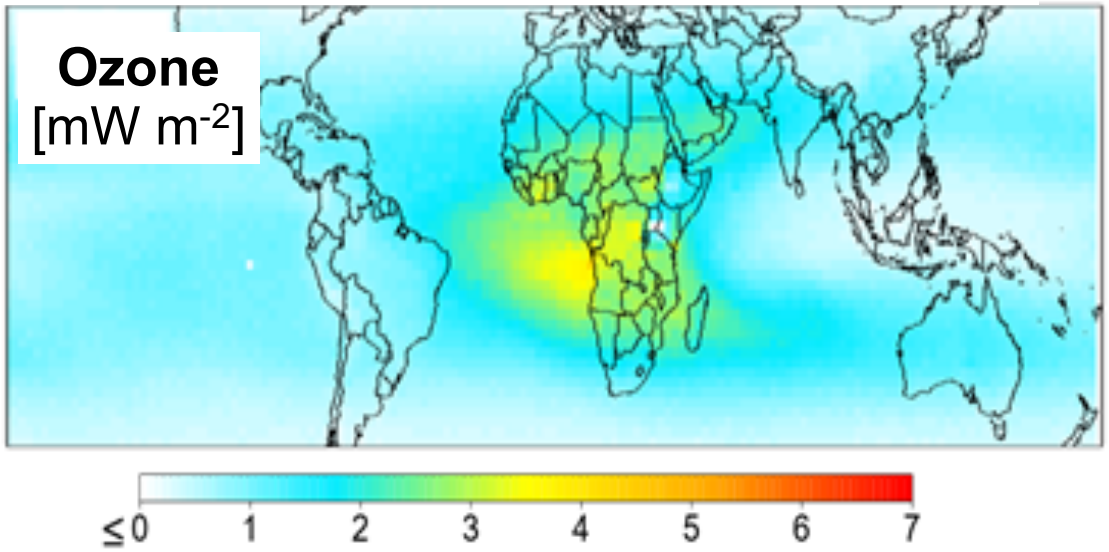
$PM_{2.5}$ > 0.8 μg m^{-3} in East Africa has serious health implications

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

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

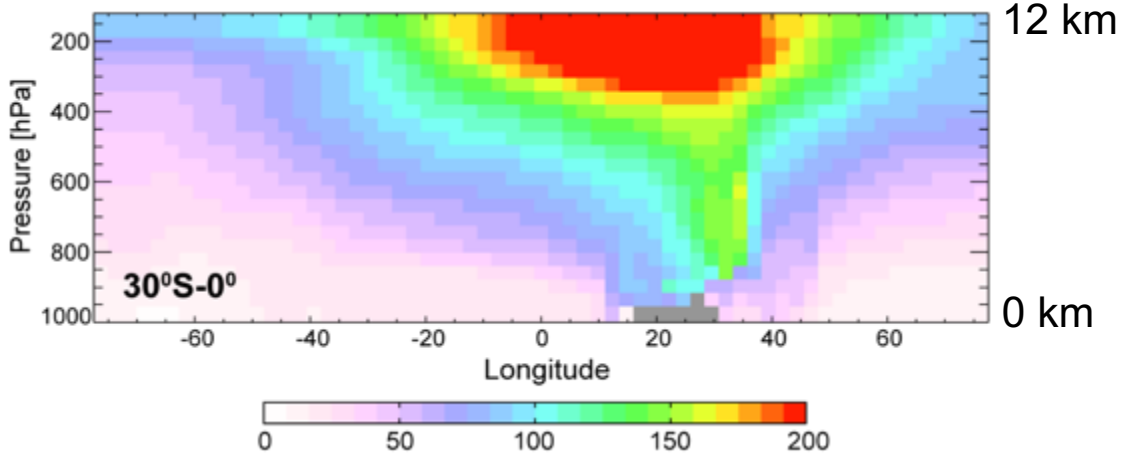
Localized effect, peaking in dense urban areas

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

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

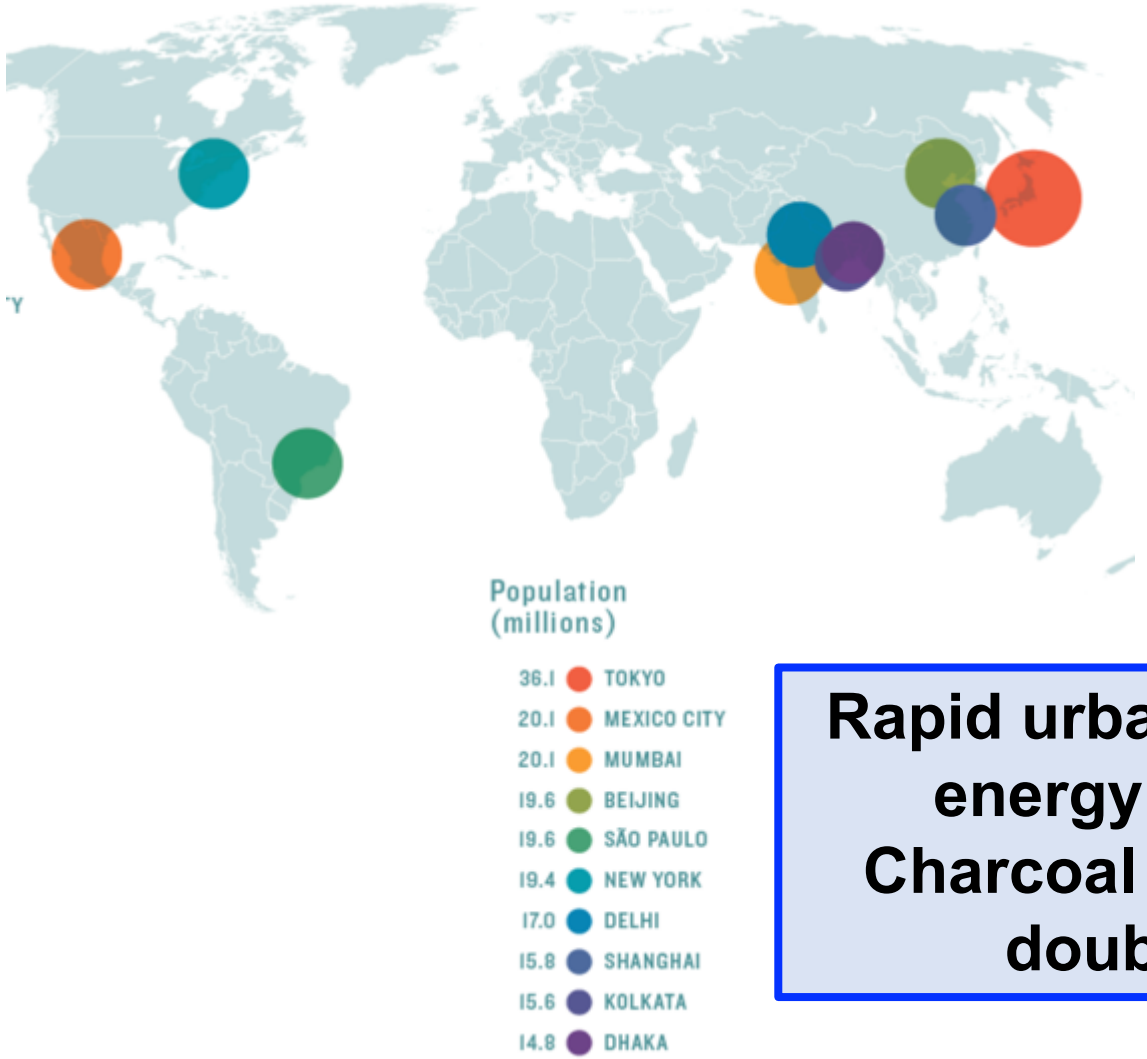
Long- and short-wave heating

Mostly due to ozone in the upper troposphere

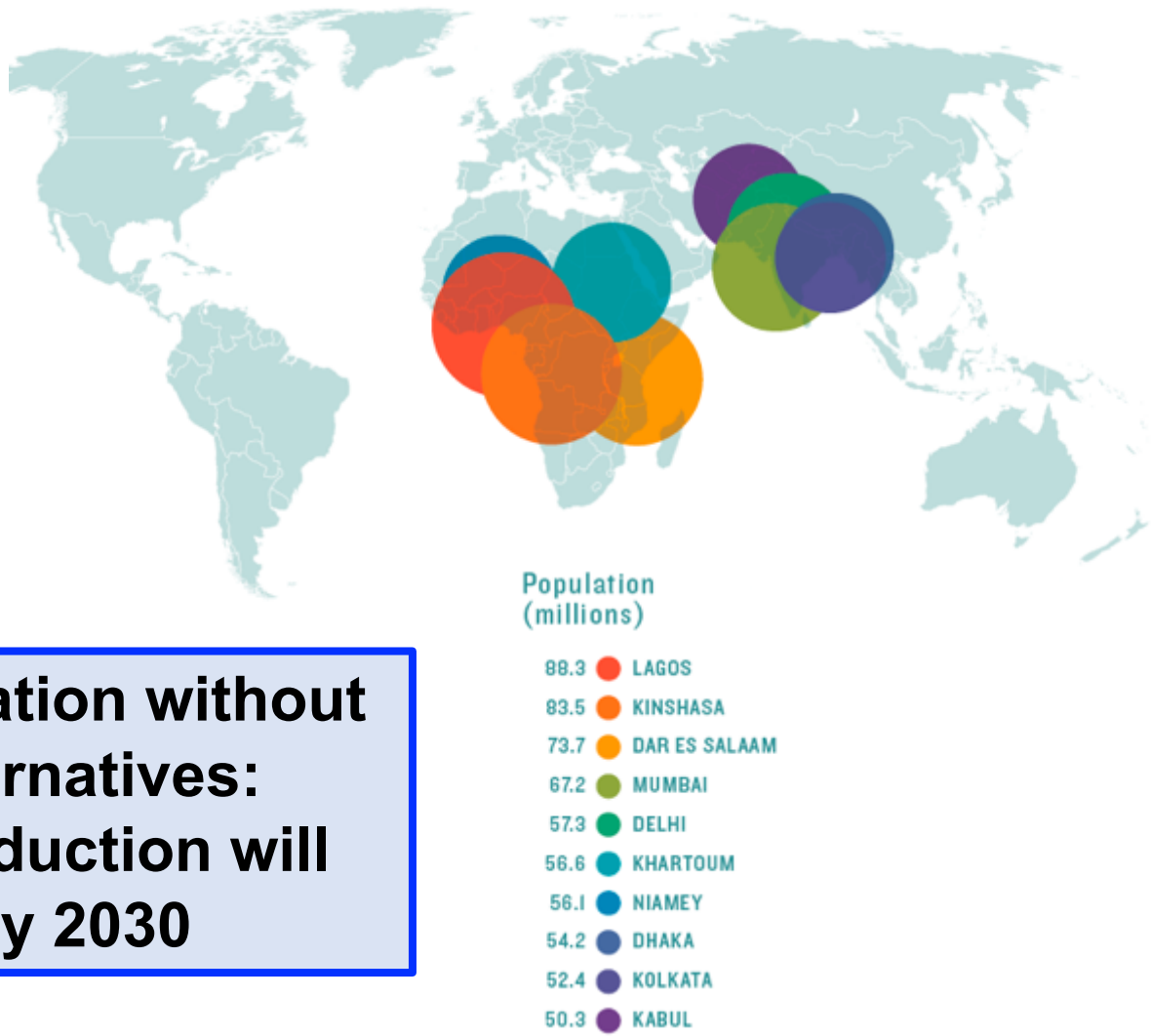


By 2100 The Largest Cities in the World Will be in Africa

2010



2100



Rapid urbanization without energy alternatives: Charcoal production will double by 2030

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