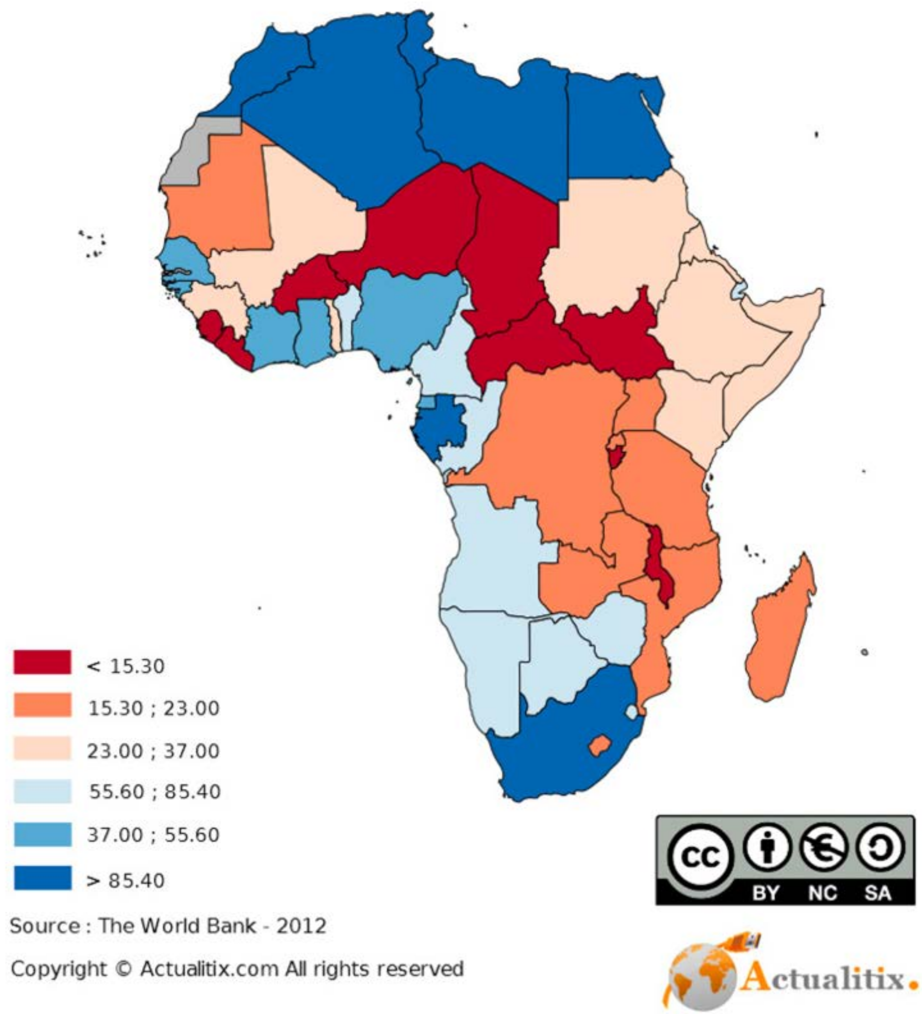
Health impact of future fossil fuels in Africa

Eloise Marais, with R. F. Silvern, L. J. Mickley,
A. Vodonos, J. Scwhartz, A. S. Bockarie

UNIVERSITY OF LEICESTER

Limited Access to On-Grid Electricity

Access to Electricity (% of population)

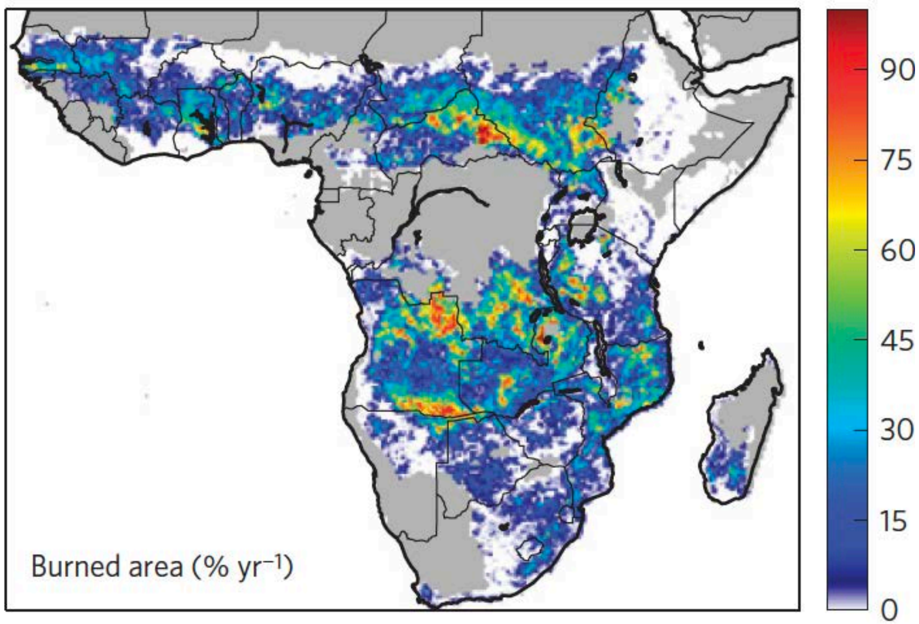


Varies from >85% for South Africa to <15% for Chad/Niger/Malawi

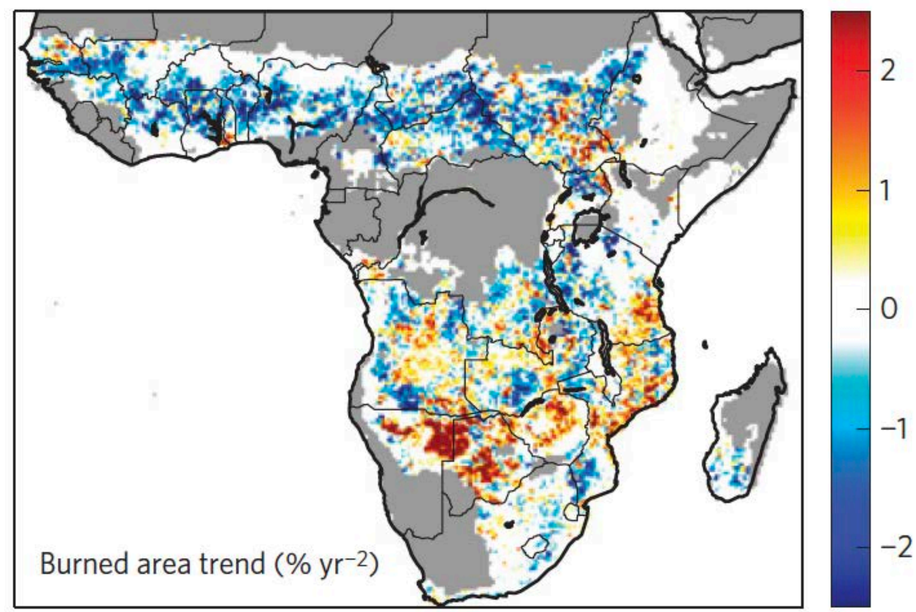
Widespread Open Burning of Biomass

Dominant contributor to surface ozone and $PM_{2.5}$

Burned area annual mean (2001-2012)



Burned area annual trend (2001-2012)

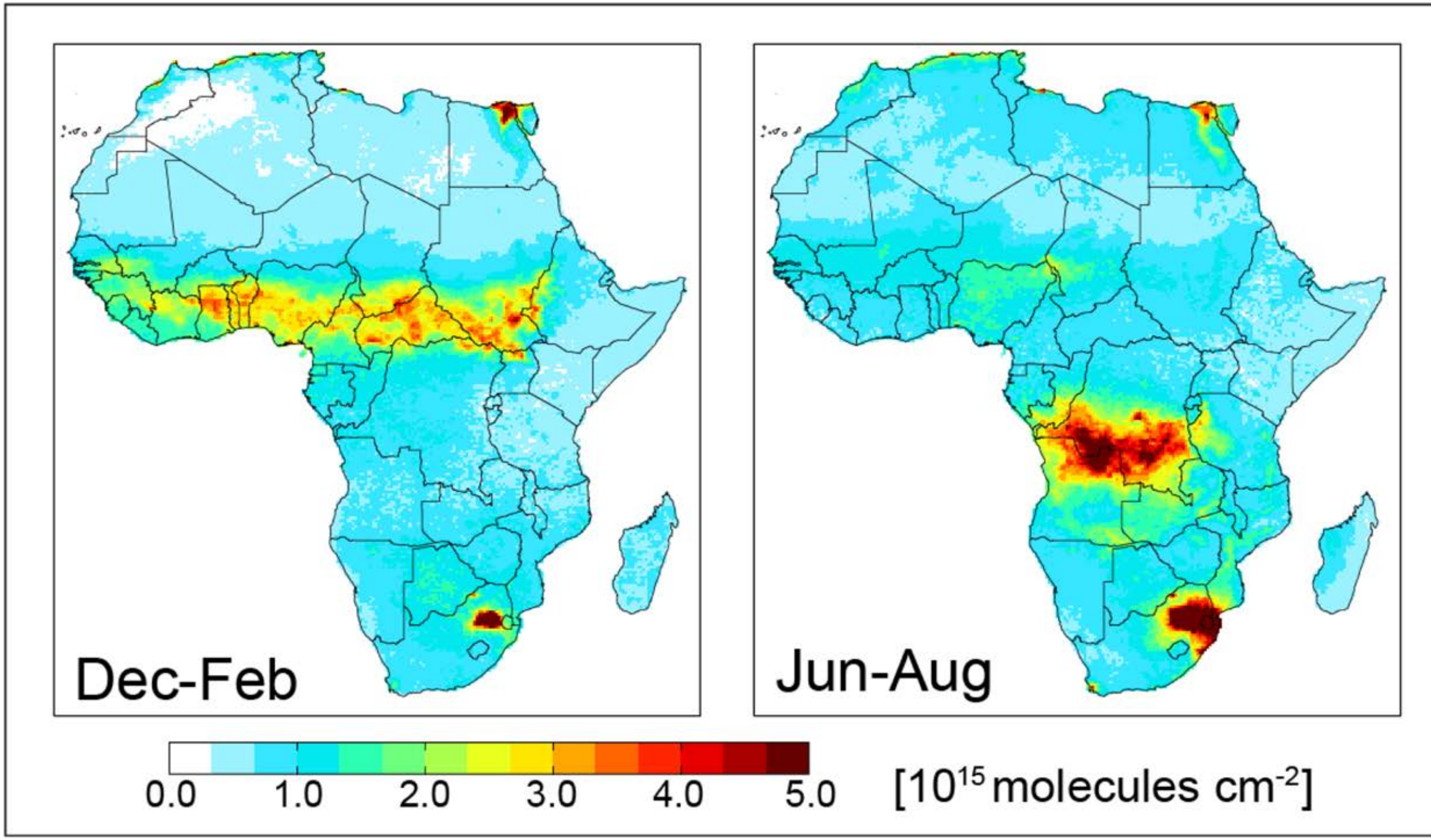


[Andela et al., 2014]

Declining north of the Equator due to changes in land cover (transition to agriculture)

Air Pollution in Africa

Seasonal mean OMI tropospheric NO_2 for 2006-2007

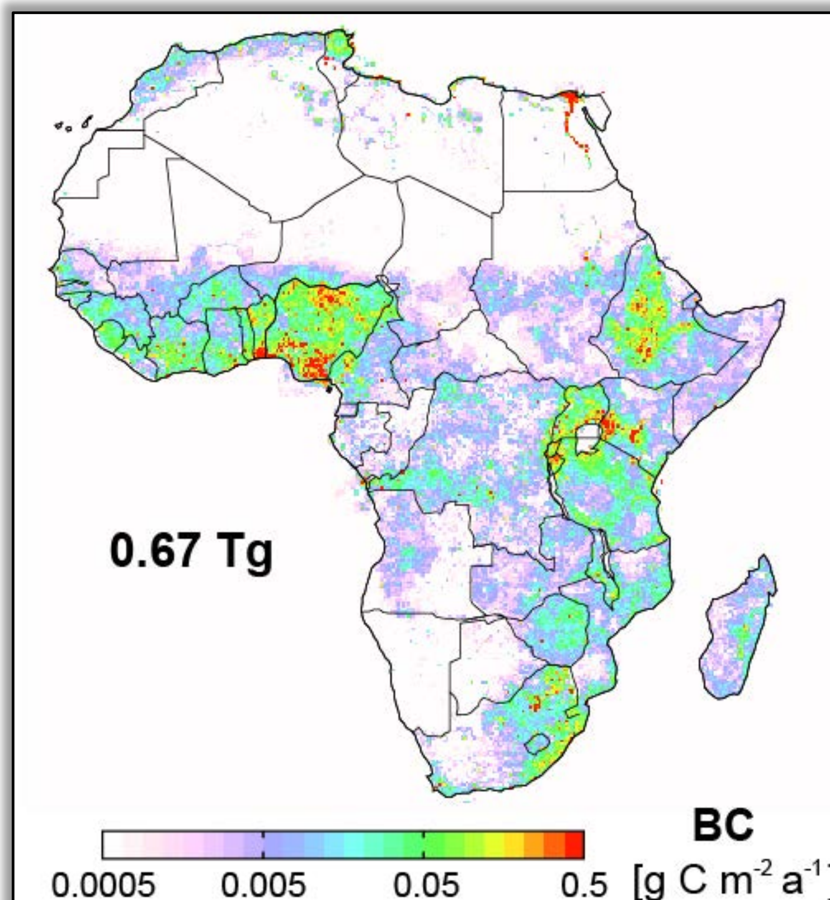


[Adapted from Marais and Chance, 2015]

Much of what we see from space is open burning of biomass

Unique mix of anthropogenic sources

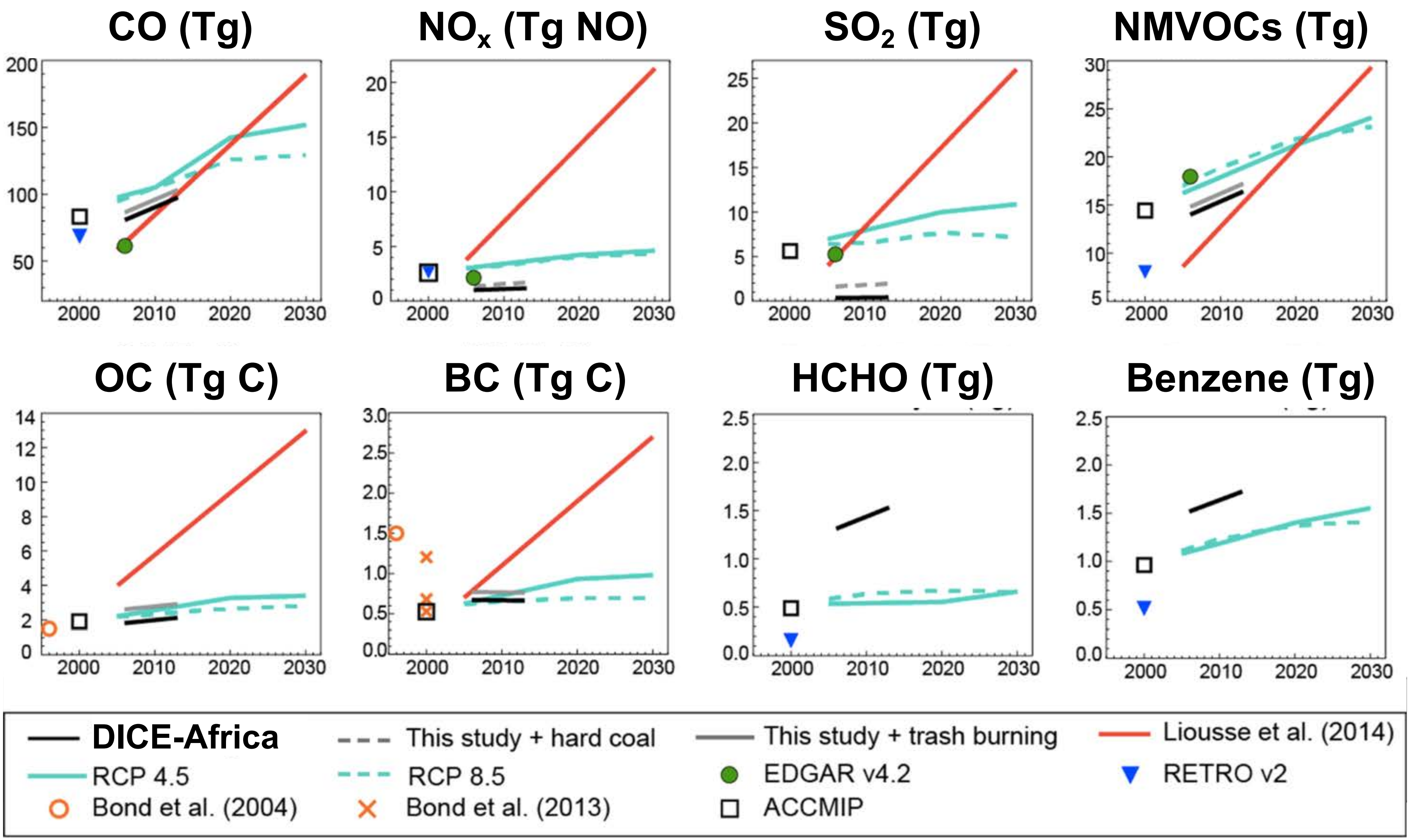
Black Carbon



[Marais and Wiedinmyer, 2016]

Similar in magnitude to emissions from open burning

Emissions Trends and Projections for Africa



Wide range of emissions trends and projections.

Future Adoption of Fossil Fuels in Africa

[Marais et al., 2019, doi:10.1021/acs.est.9b04958]

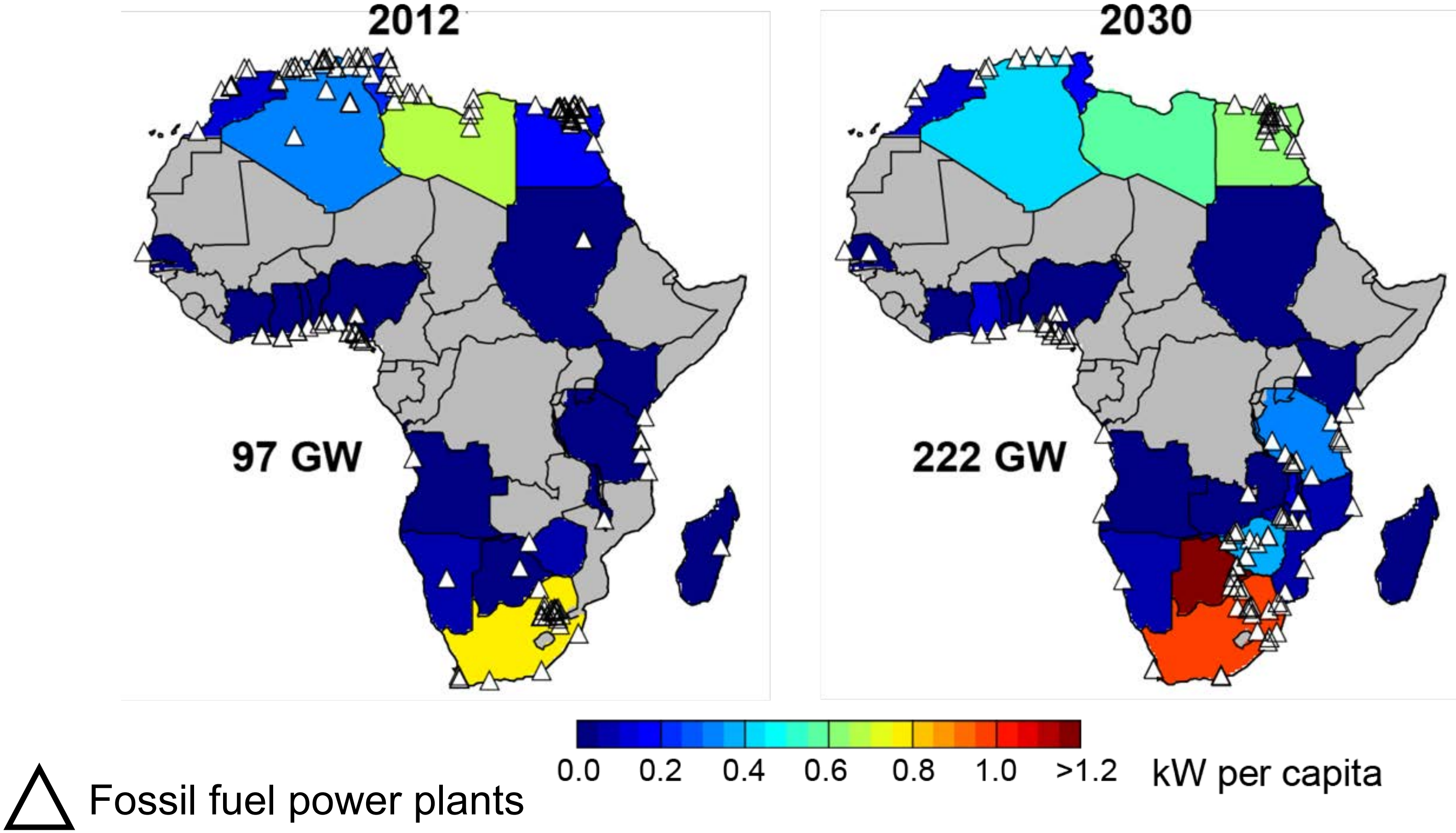
ENDCOAL

ENDCOAL.ORG

The Wallace Foundation®

Coal and Natural Gas Use in Africa

Per capita generating capacity



Generating capacity to increase by almost 300%
(mostly North and southern Africa)

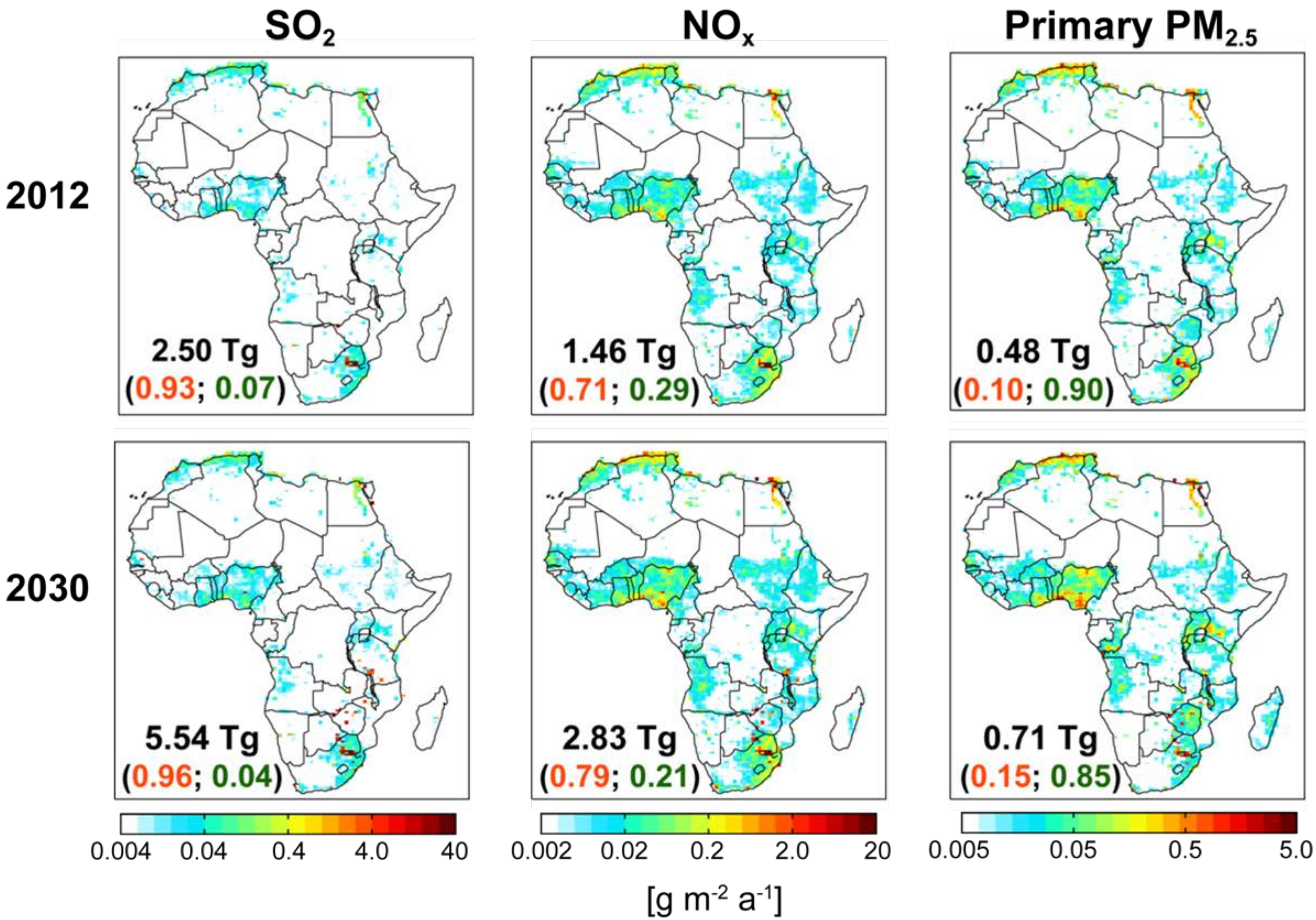
... And also Powerships

Interim solution for a country to increasing generating capacity

Run on **bunker fuel**

Already in use in Ghana and Mozambique (Zambia)

Emissions from current and future fossil fuels

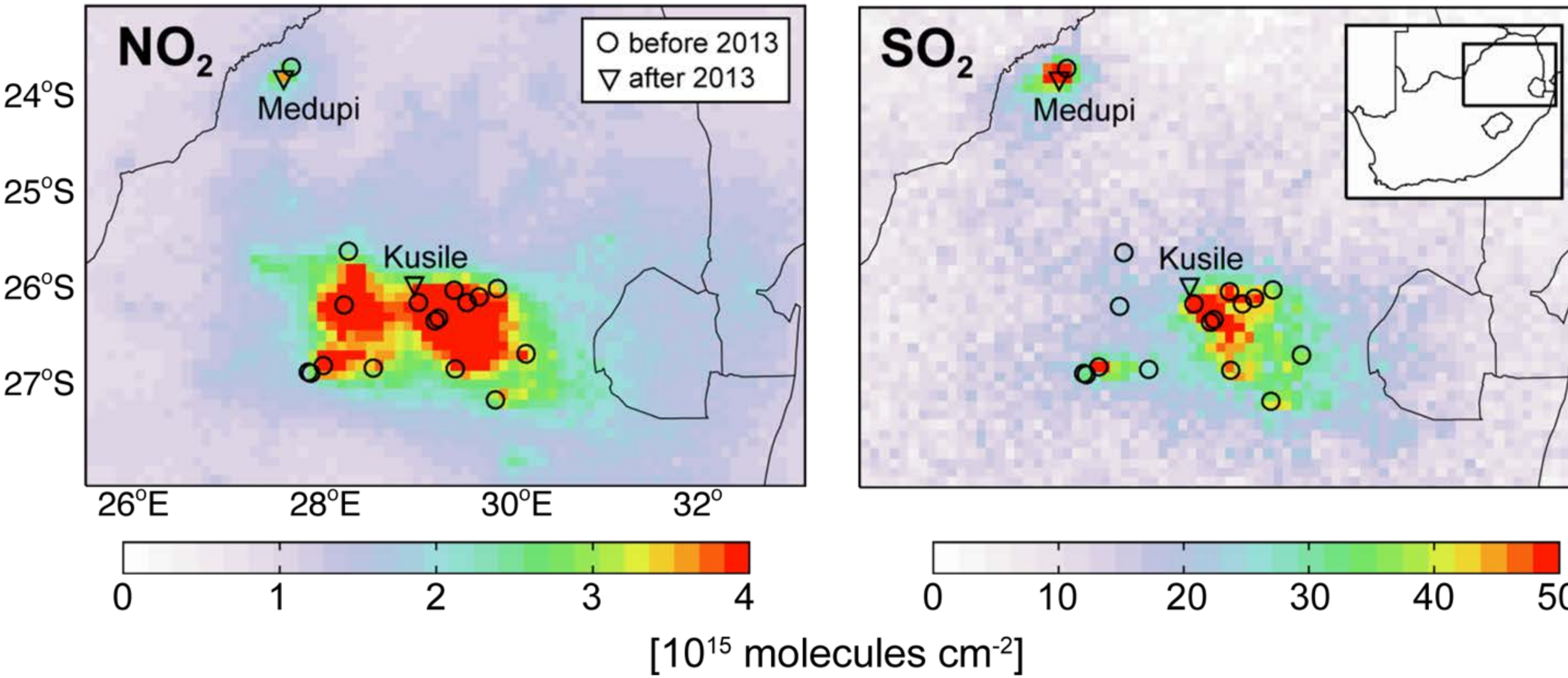


Black: total continent emissions

Fractional contribution from power plants (**orange**) and vehicles (**green**)

Evidence of AQ Degradation from Space

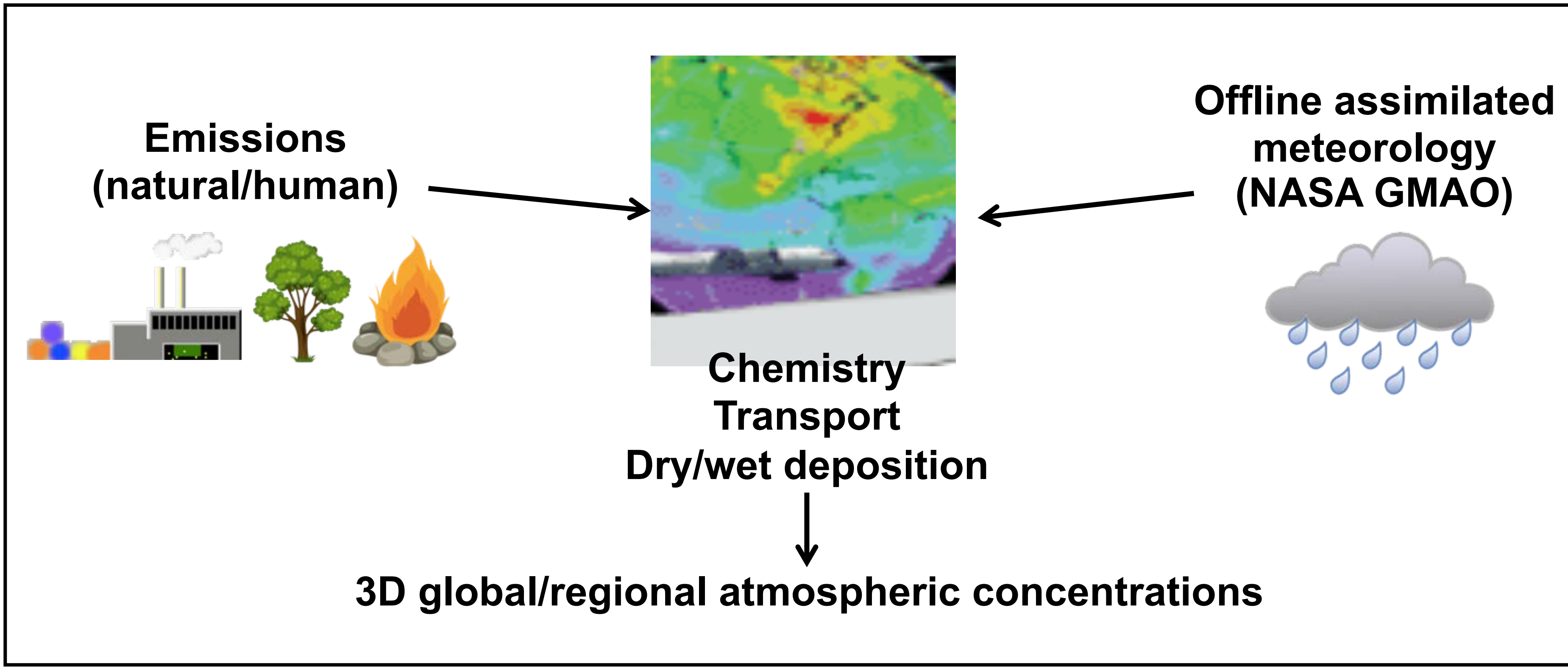
TROPOMI NO_2 and SO_2 at 0.1º x 0.1º for May-Sep 2018



Satellite observations support air quality degradation at the location of the new Medupi power plant

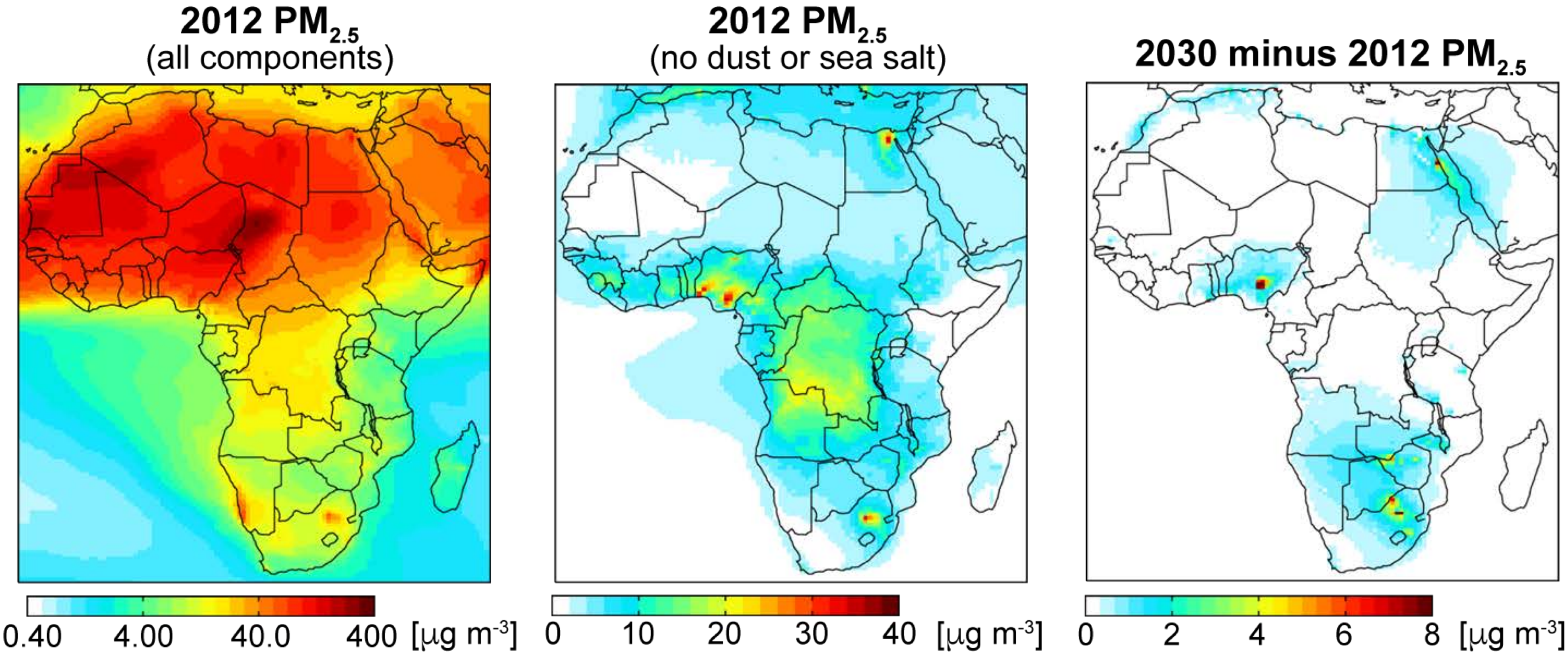
Model $PM_{2.5}$ and ozone from future fossil fuels

GEOS-Chem



Model is nested over Africa at 50-67 km

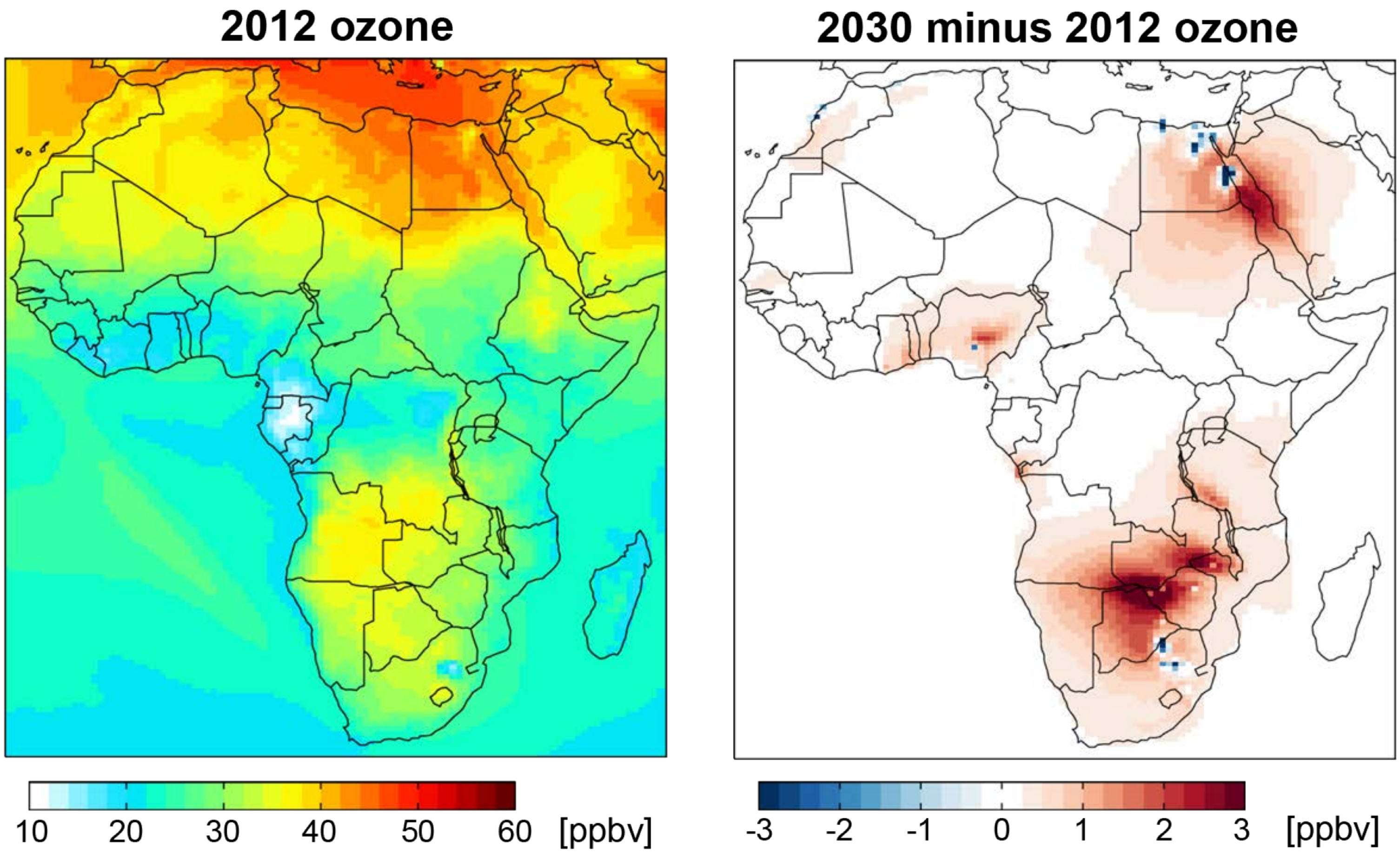
Current $PM_{2.5}$ and the contribution from future fossil fuels



Absolute contribution dominated by dust

>8 $\mu g\ m^{-3}$ increase in locations in Nigeria, Egypt and South Africa

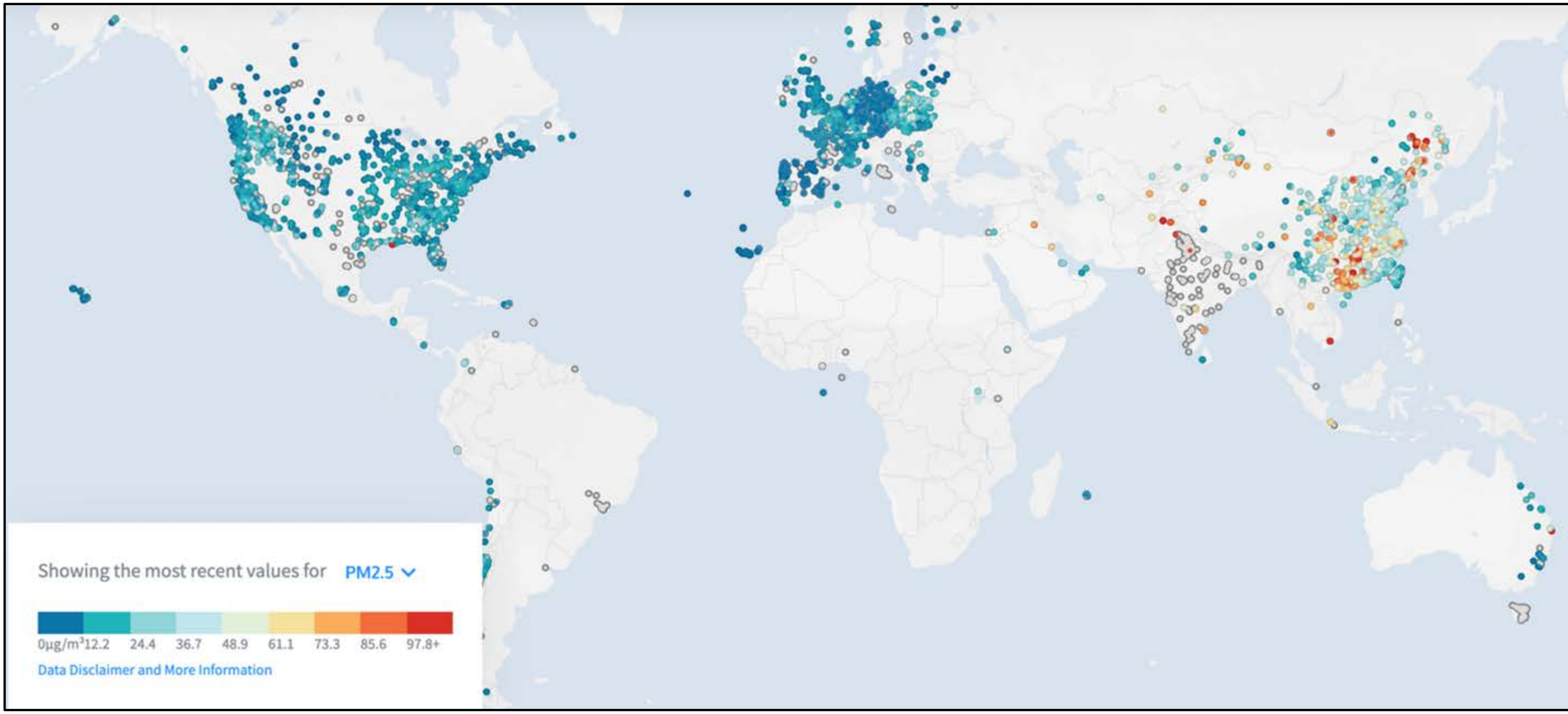
Model current ozone and the future fossil fuel contribution



NO_x titrates ozone at densely populated areas and point sources

2-3 ppbv increase may impact agricultural productivity

How close is the model to reality?

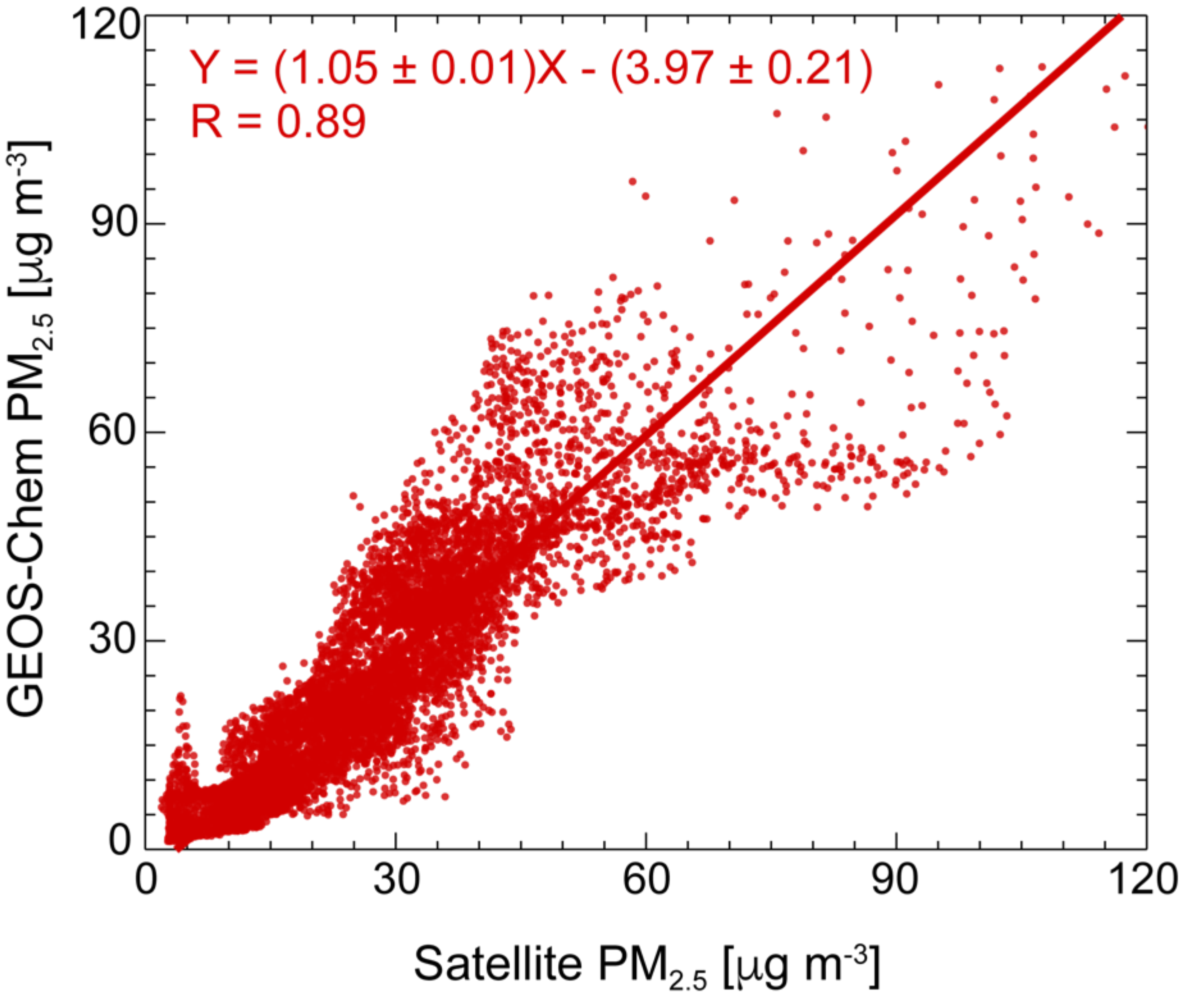


[OpenAQ, Accessed 10 November 2019]

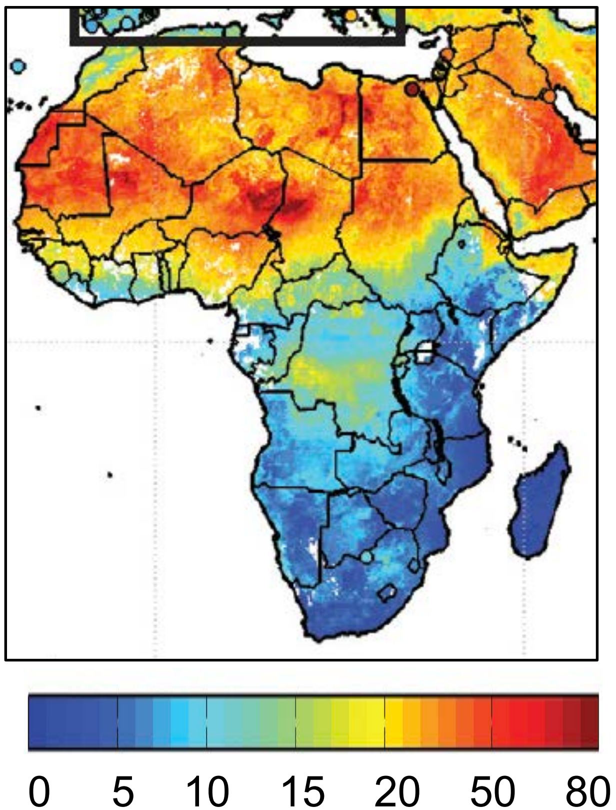
Open access, reliable $PM_{2.5}$ and ozone measurements severely limited

Turn to $PM_{2.5}$ derived with satellite observations of AOD

Comparison of model and satellite-derived $PM_{2.5}$ across Africa



Annual mean satellite-derived $PM_{2.5}$ ($\mu g\ m^{-3}$)

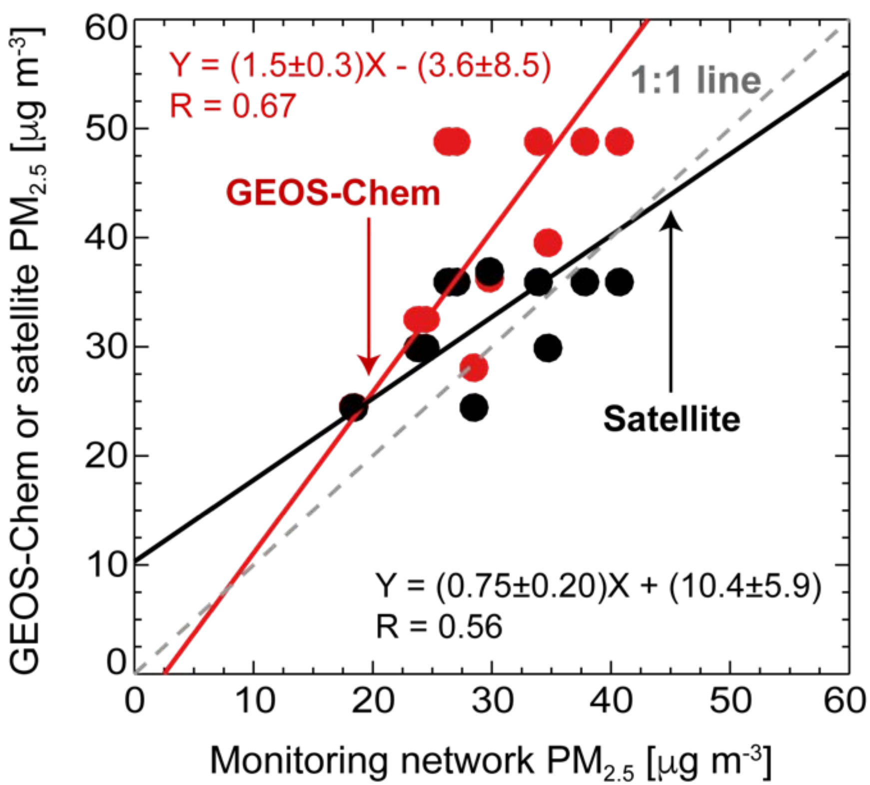


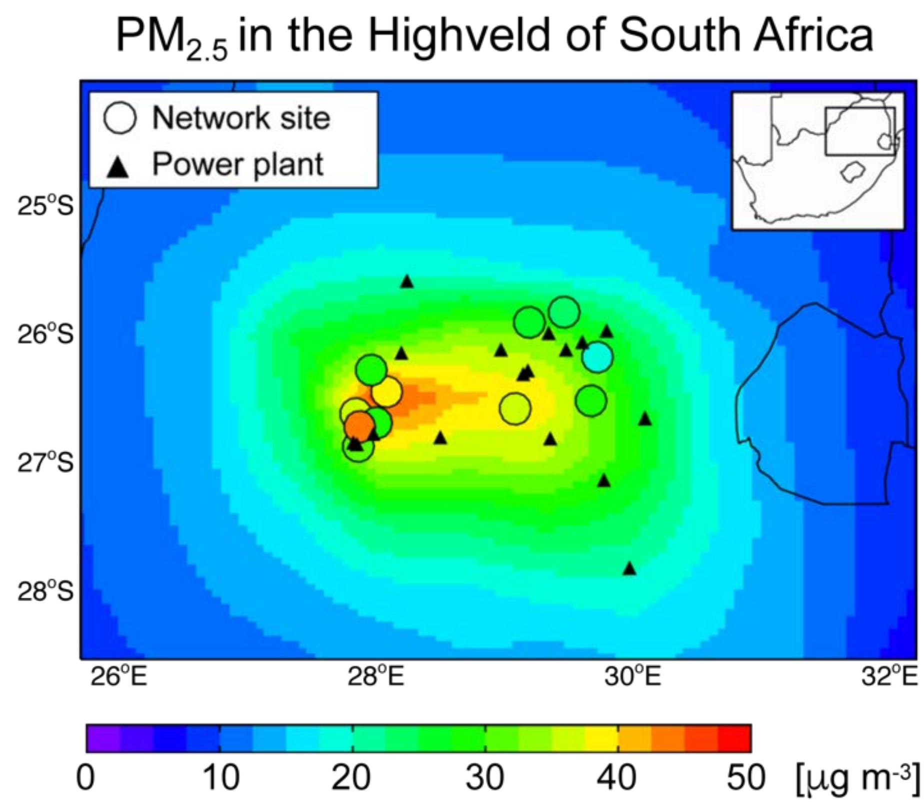
[van Donkelaar et al., 2010]

Consistent and unbiased after reducing windblown dust emissions by 40%

... And quality checked network observations

Comparison of model and satellite-derived $PM_{2.5}$ to surface observations limited to South Africa

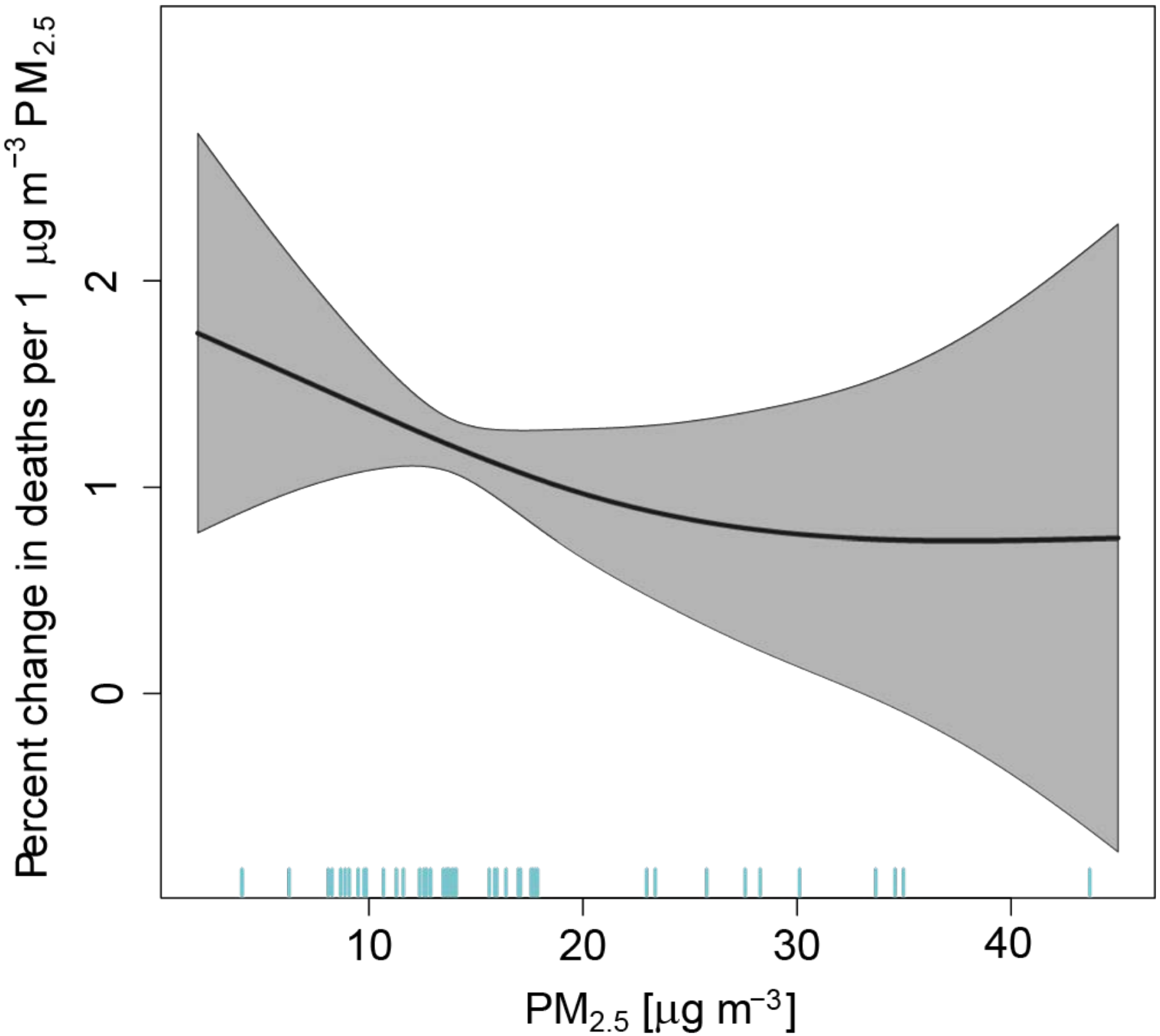




[$PM_{2.5}$ annual means from Garland et al. (2013)]

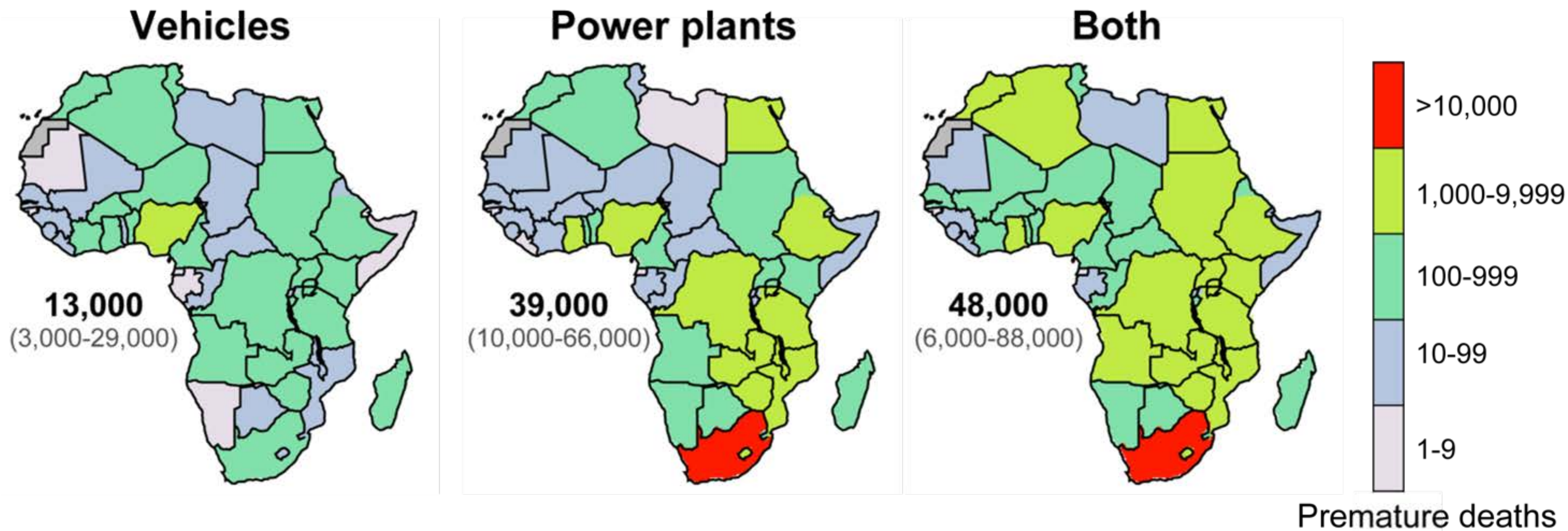
Model overestimates $PM_{2.5}$ due to overestimate in trash burning

Premature Mortality due to $PM_{2.5}$ Exposure



Use the concentration-response function of Vodonos et al. (2018) that includes exposure at $PM_{2.5}$ > 40 $\mu g\ m^{-3}$

Annual Avoidable Deaths in 2030

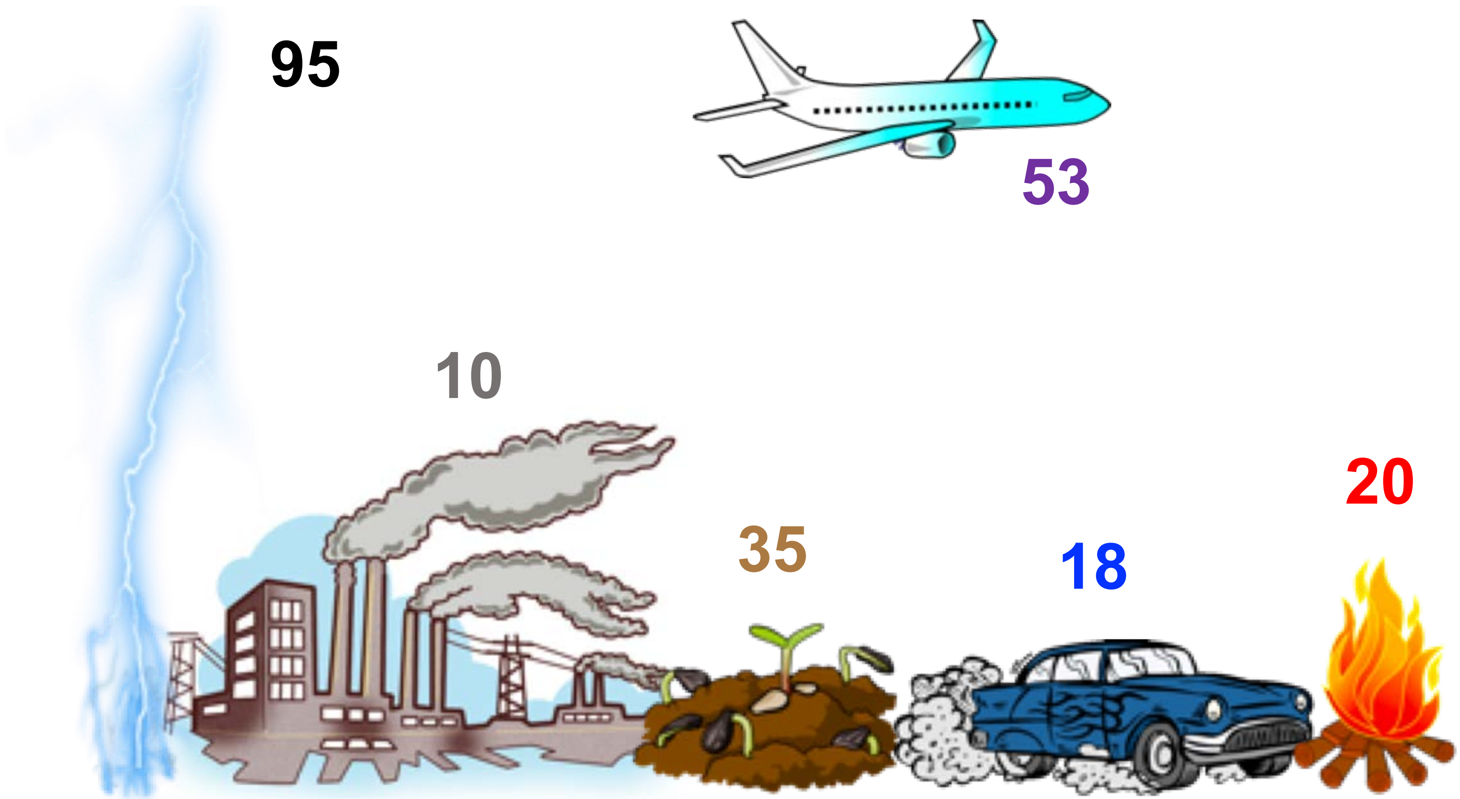


Total for Africa: **48,000** in 2030

Factor of 3 larger contribution from power plants than transportation

Reactive Nitrogen in the Upper Troposphere

Ozone production efficiency from NO_x sources



[adapted Dahlmann et al., 2011]

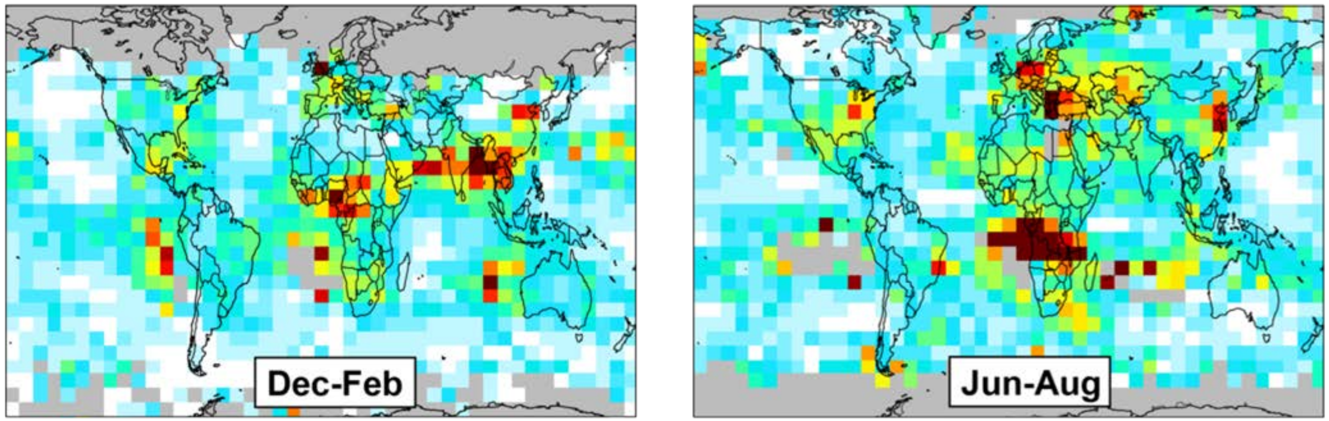
Greater ozone production efficiency in the upper troposphere than the surface

Measurements of NO_x in the upper troposphere are very limited

Constraints from UT NO_2 products

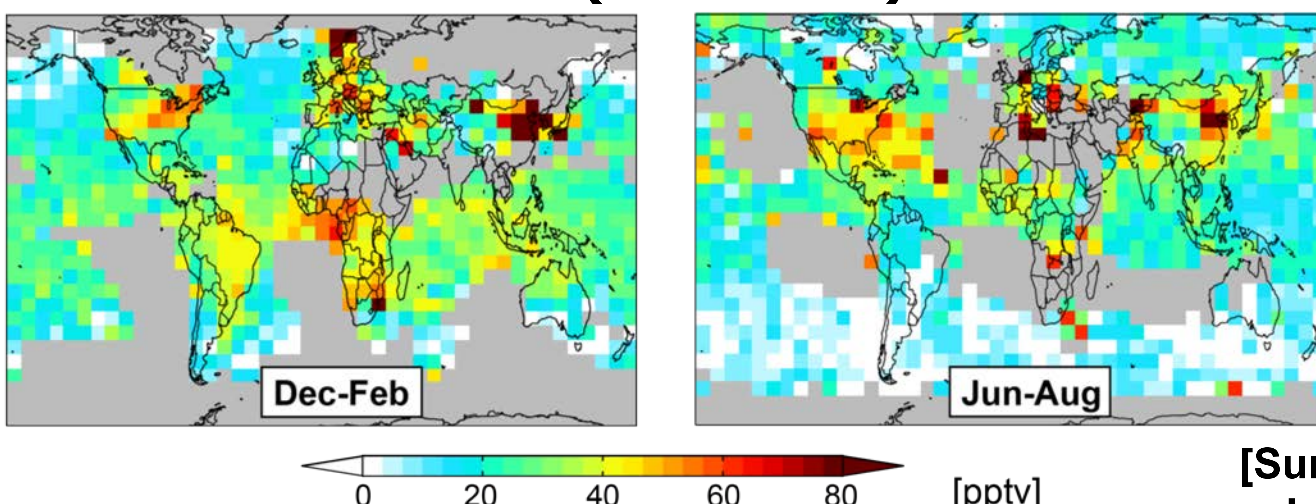
[Marais et al., 2018, doi:10.5194/acp-18-17017-2018]

KNMI (2006)



[Maria Belmonte-Rivas]

NASA (2005-2007)

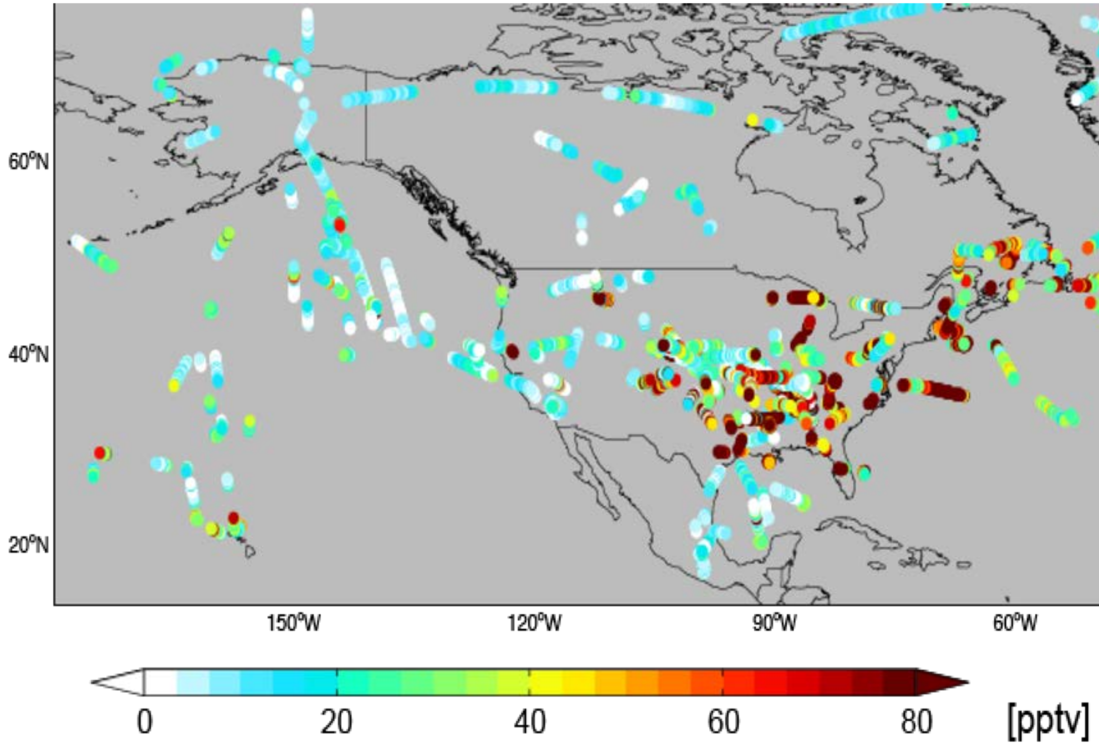


[Sungyeon Choi, Joanna Joiner]

Inconsistent: poor spatial correlation, KNMI 16-48% lower than NASA

Arbitrate with aircraft observations of NO_2

Spring-summer multiyear aircraft campaigns from the NASA DC8 aircraft

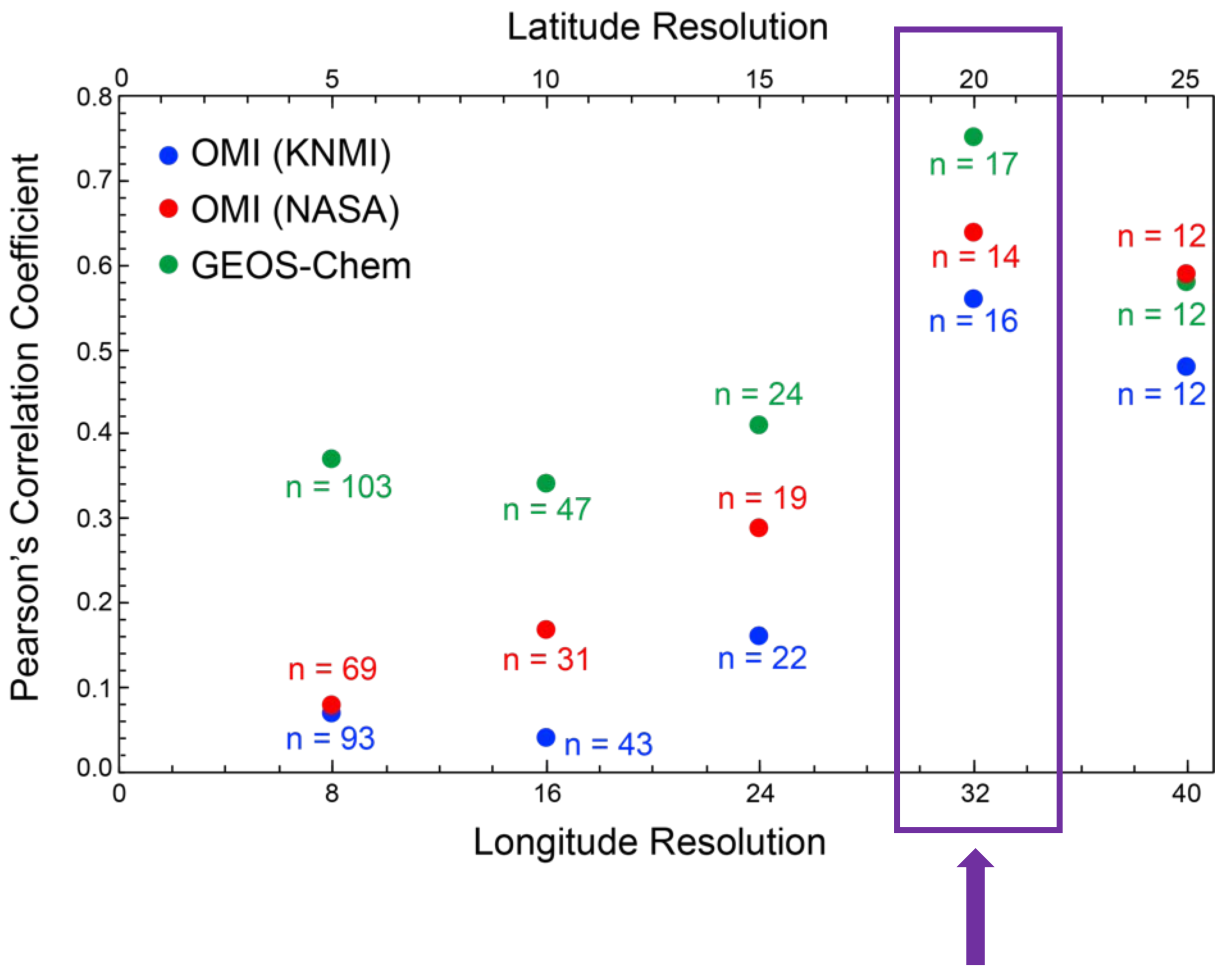


[Ron Cohen's TD-LIF instrument]

Campaigns extend from 2004 (INTEX-A) to SEAC^{4}RS (2013)

Arbitrate with aircraft observations of NO_2

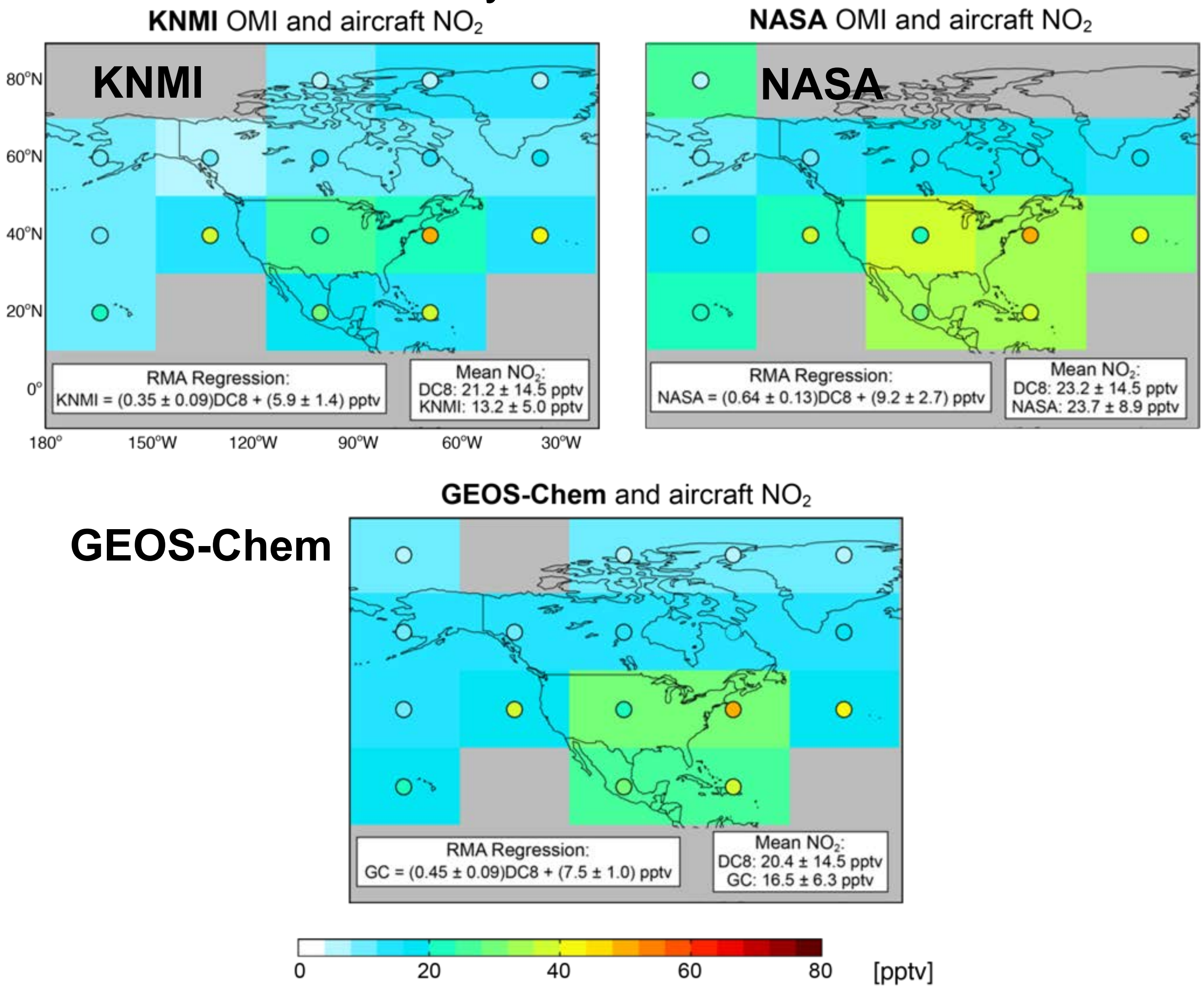
Spatial consistency of aircraft and satellite observations



Greatest consistency at 20° × 32° (~2000 km × 3200 km)

Arbitrate with aircraft observations of NO_2

Quantitative consistency of aircraft and satellite observations

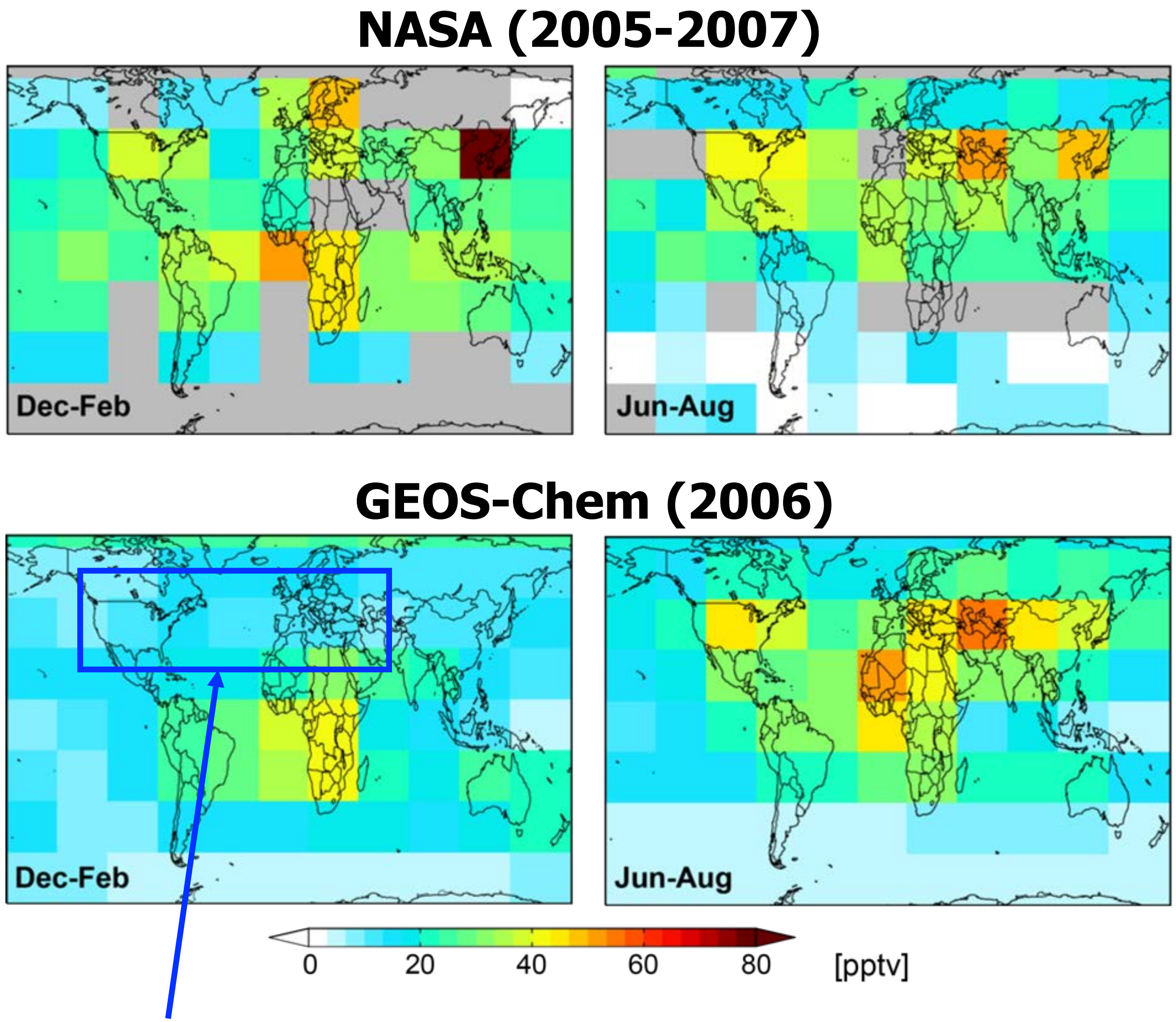


NASA more consistent with aircraft observations than KNMI

Satellite and model overestimate background, underestimate variability

Evaluate against GEOS-Chem

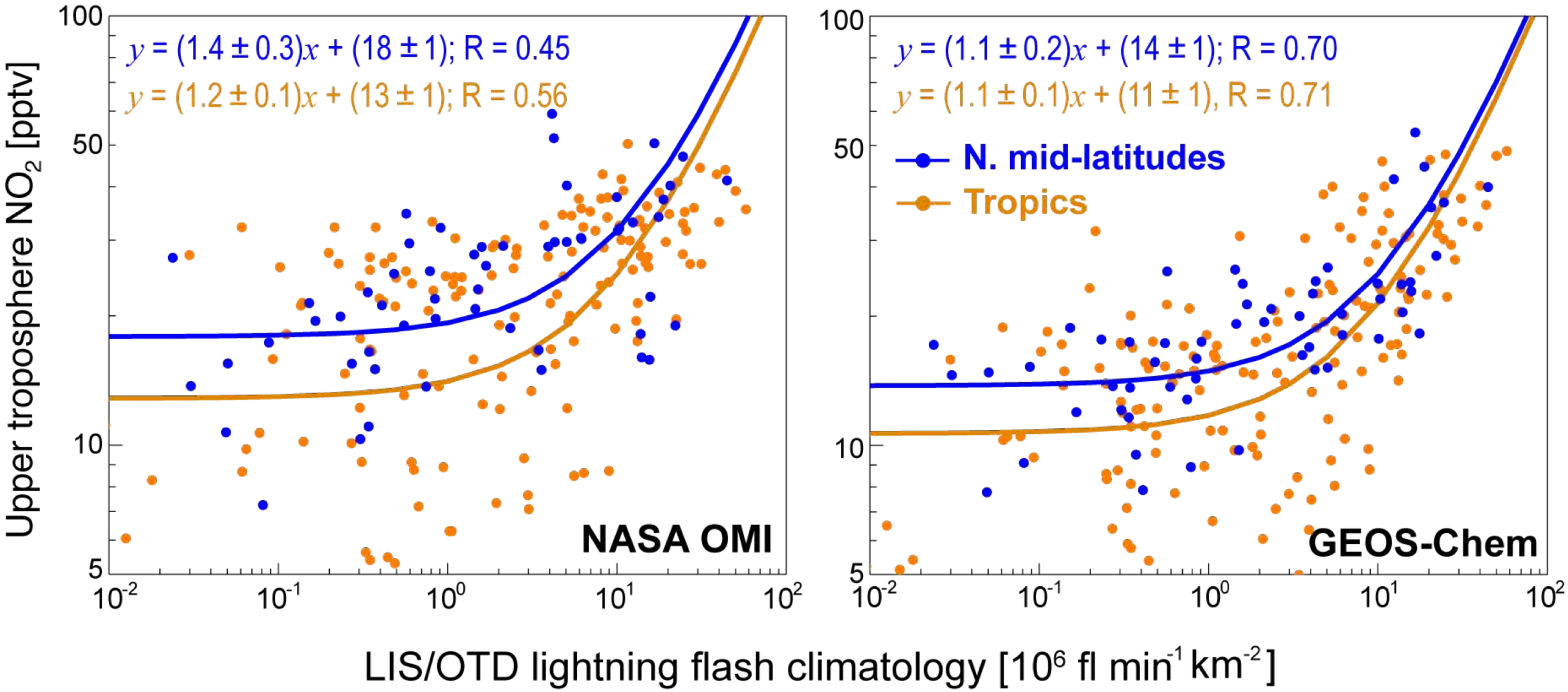
GEOS-Chem: represents best understanding of atmospheric chemistry



Model underestimates NO_x in the midlatitudes in winter by 20-40 ppbv

New Constraints for lightning NO_x

Regression of UT NO_2 against satellite observations of lightning flashes



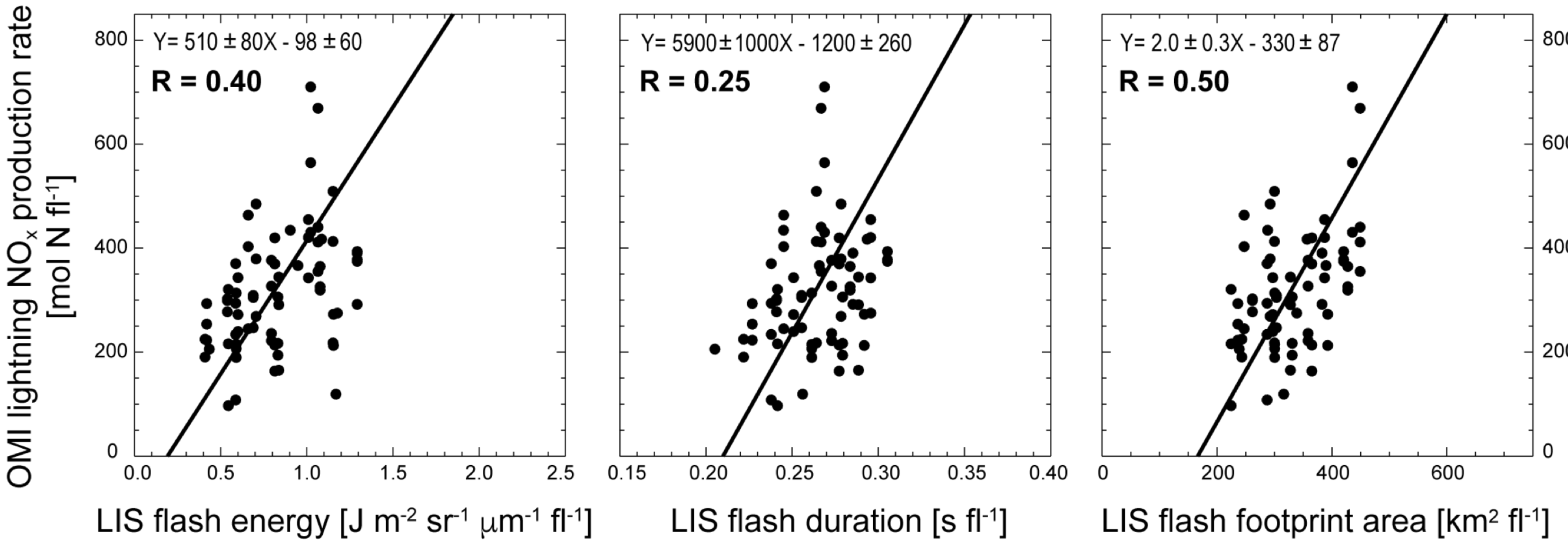
Linear fit shown in log-log space to show background NO_2 (10-20 ppbv)

No support for high **lightning NO_x production rates** in the midlatitudes (500 mol nitrogen per flash) than the tropics (260 mol nitrogen per flash)

Satellite-derived NO_x Yields per Flash

Obtain from the discrepancy between the satellite and the modelled UT NO_2

OMI-derived lightning NO_x production rates versus lightning properties



[Lighting properties from Beirle et al., 2014]

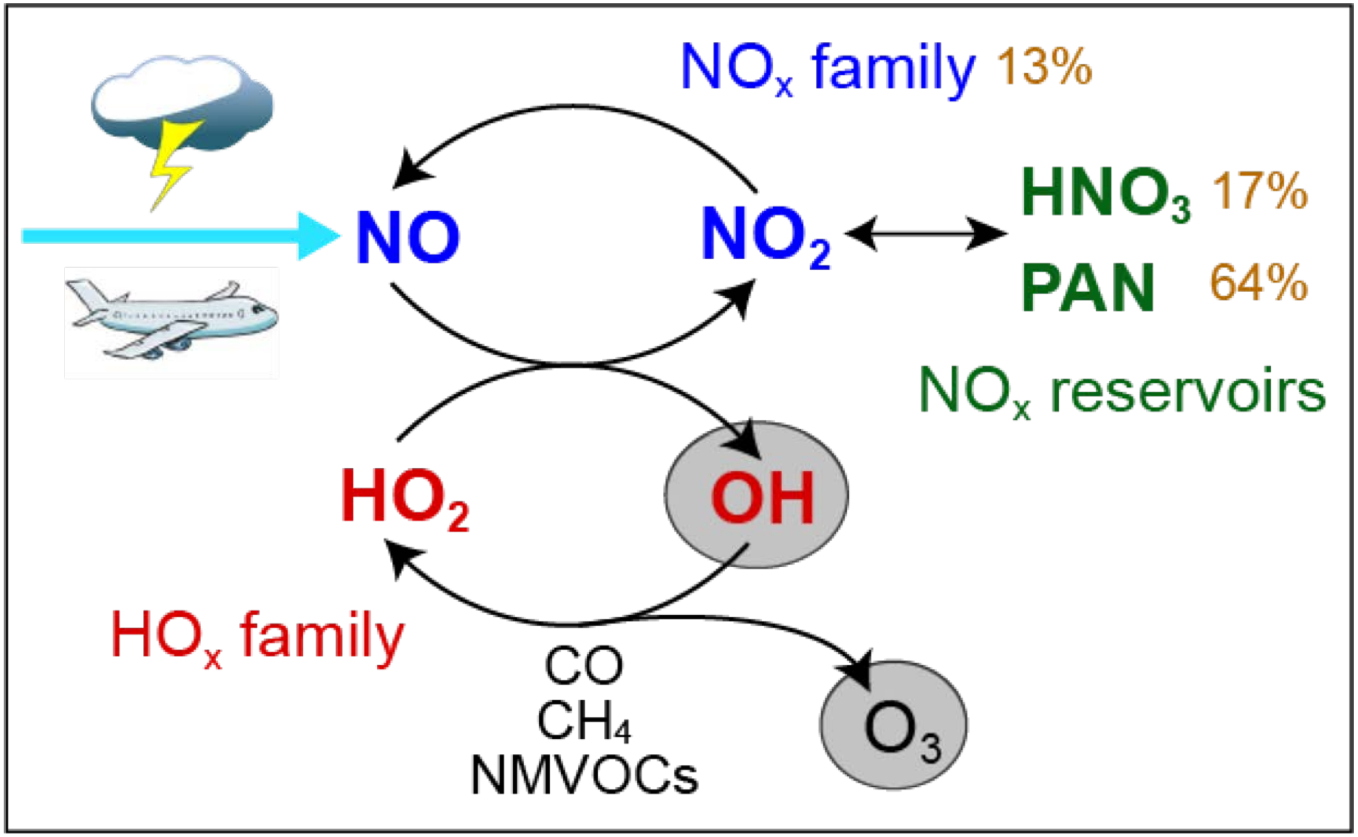
NO_x yield per flash increases with **lightning flash energy** and **footprint**

Global annual lightning NO_x emissions using OMI UT NO_2: **5.9 Tg N**
(literature review range: **3-7 Tg N**)

Global average lightning NO_x production rate: **280 mol N flash^{-1}**

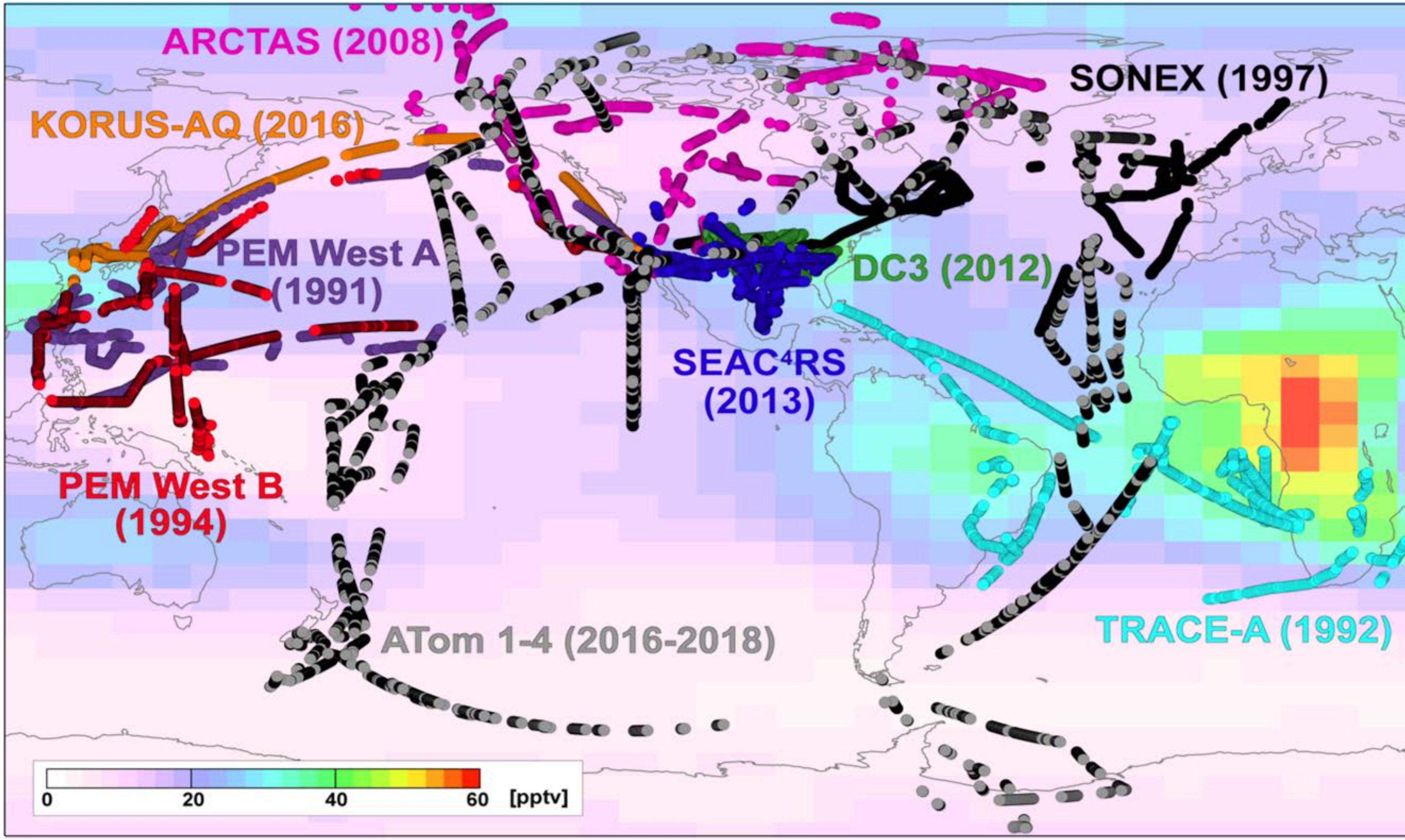
Challenge our understanding of reactive nitrogen in the global upper troposphere

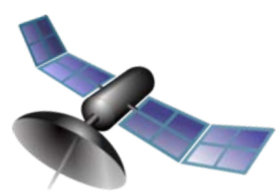
Errors in processes in the upper troposphere propagate as large errors in ozone and OH



Affects air quality and climate estimates from models and satellite observations

Produce a climatology of global NO_y in the UT



Circles:  **Background:**  (synthetic)

I’m Recruiting: Spread the Word!

ERC UpTrop Project:

Go to http://maraisresearchgroup.co.uk/joinus.html:

2 postdoc positions linked to the ERC project
Closing date: 11:59pm Friday 15 November

2 PhD positions soon to be advertised linked to the ERC project

Environmental Science PhD studentships:

Go to http://centa.org.uk

2 PhD projects as lead supervisor

1 PhD project as co-supervisor