# The Future of Air Pollution in Africa

UCL


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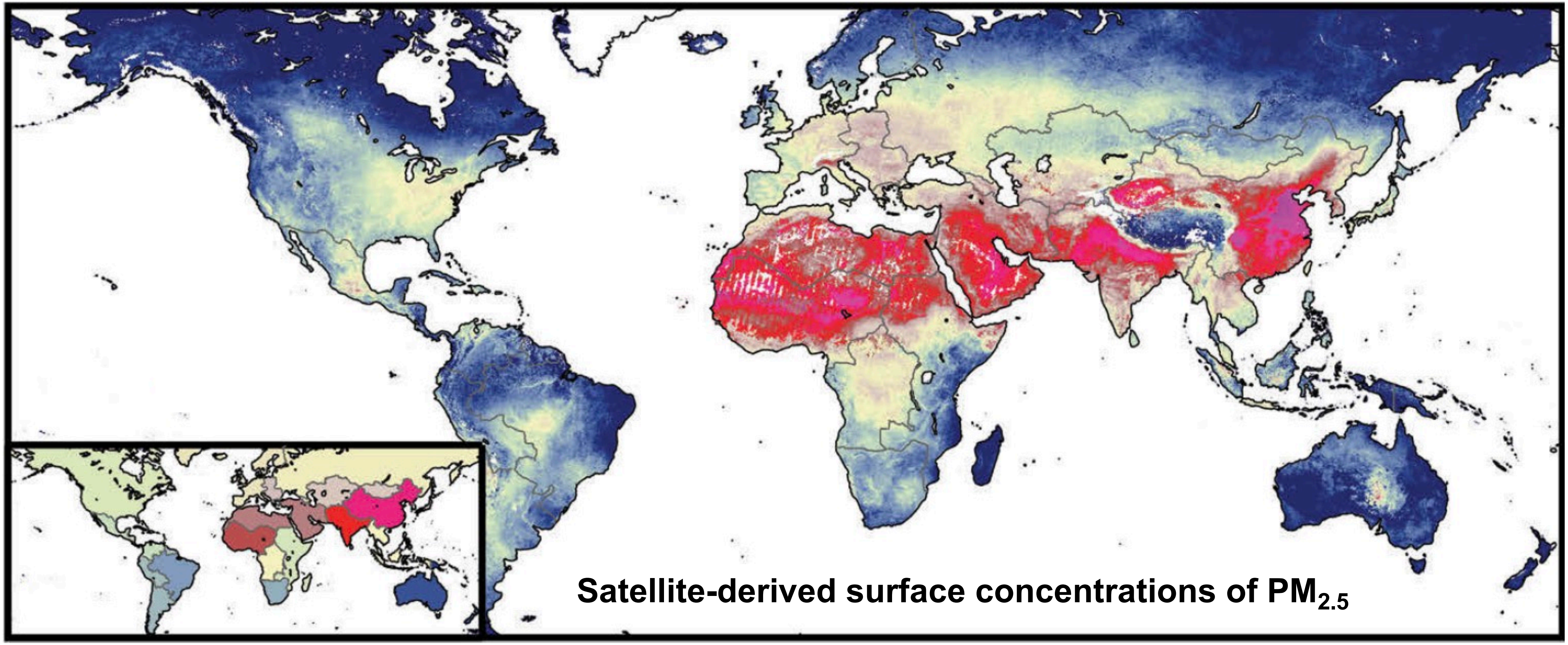
# Air pollution in Africa is dominated by non-industrial sources

Mass concentrations of fine particles ($PM_{2.5}$) in Africa comparable to other hotspots




**[van Donkelaar et al., 2015]**

Sources of $PM_{2.5}$ mostly from Saharan dust and seasonal open burning of biomass

# Unique mix of anthropogenic inefficient combustion sources

Anthropogenic emissions diffuse, but similar in magnitude to emissions from open fires

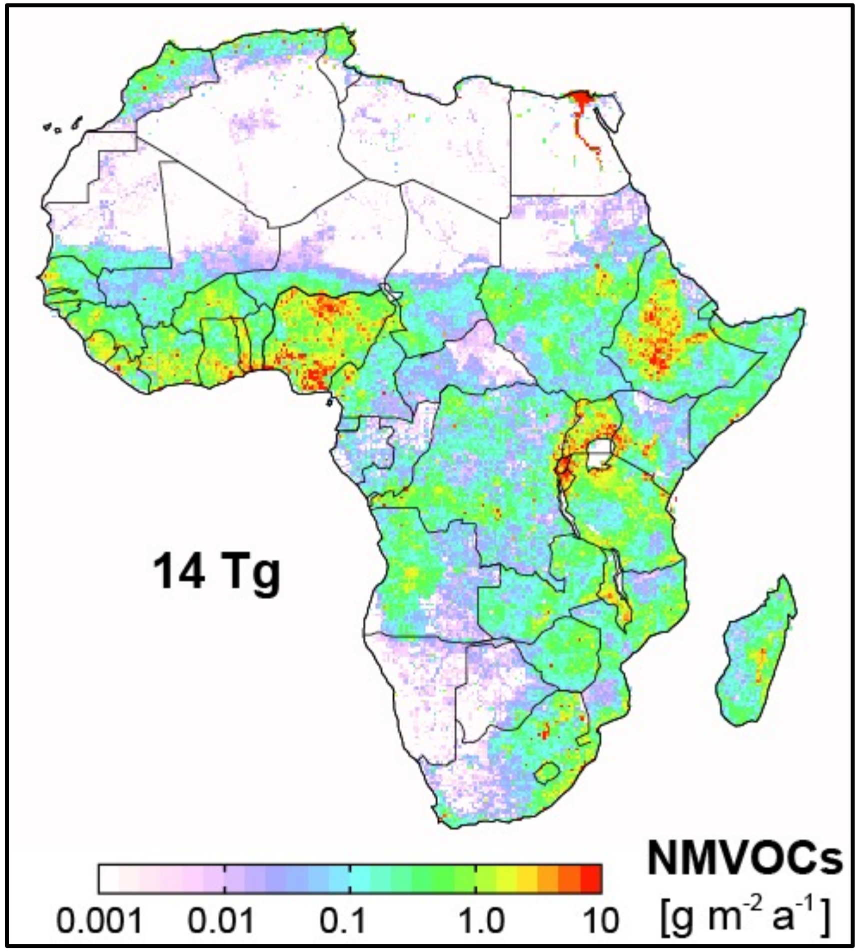
**Cooking**

**Flares**

**Ad hoc oil refining**

**Kerosene lamps**

## NMVOCs Emissions for 2006 from DICE-Africa




[Marais & Wiedinmyer, 2016]

**Transport**

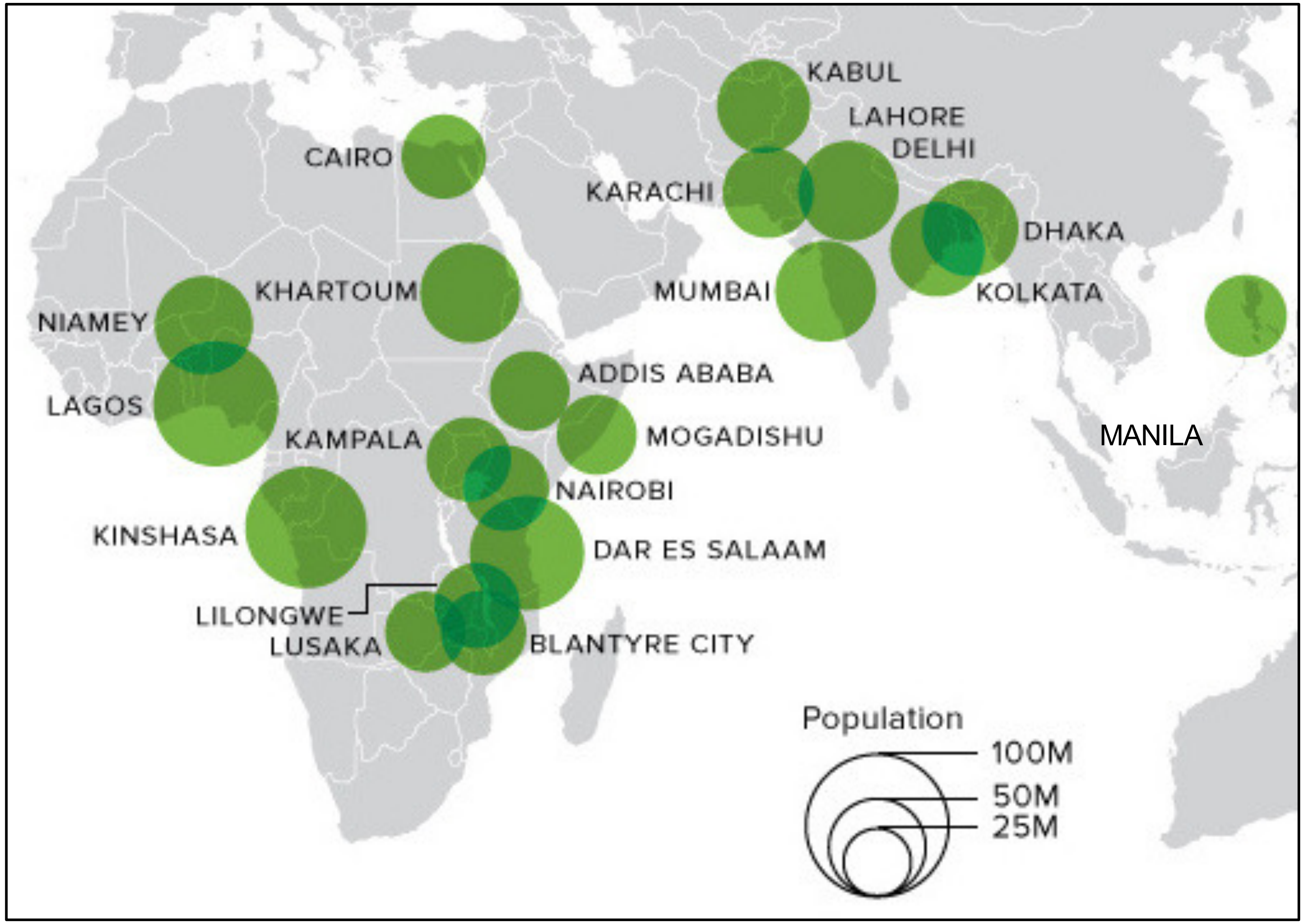
**Motorbikes**

**Generators**

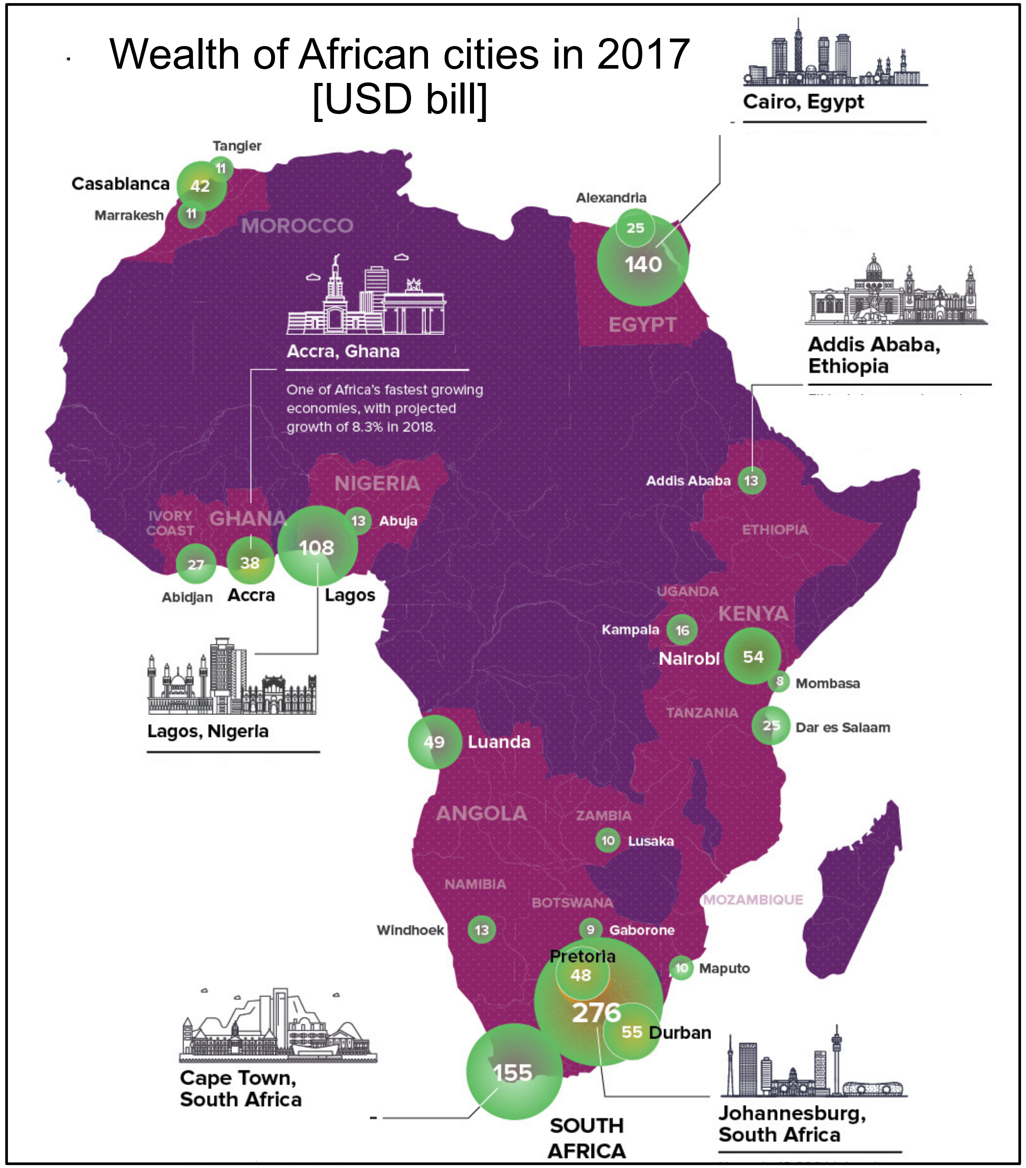
**Charcoal making**

# Africa is poised for rapid growth

## Most populous megacities will be in Africa in 2100




## Economic development less certain




**[Both maps from www.visualcapitalist.com]**

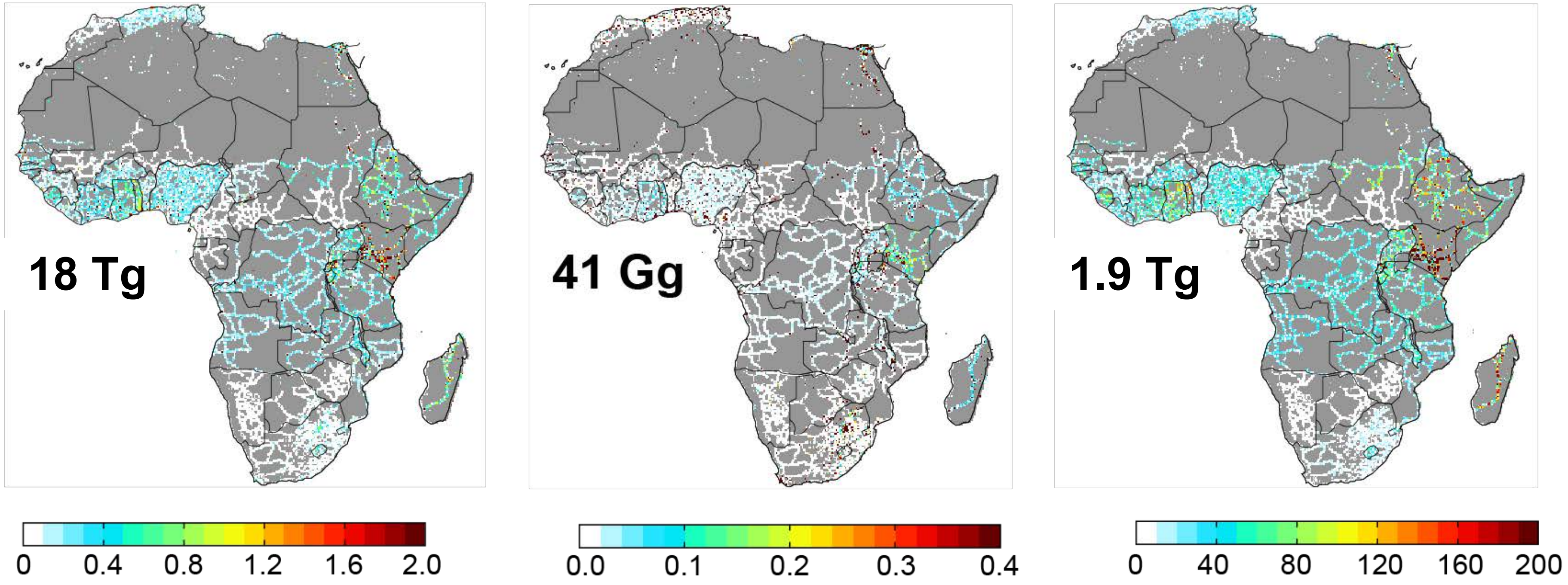
## Mix of energy options will determine future air quality

# Solid fuels like charcoal are still dominant energy sources

Charcoal production and use is increasing by 7% per year, as alternate options like LPG are costly, fluctuate in cost, and supplies are unreliable

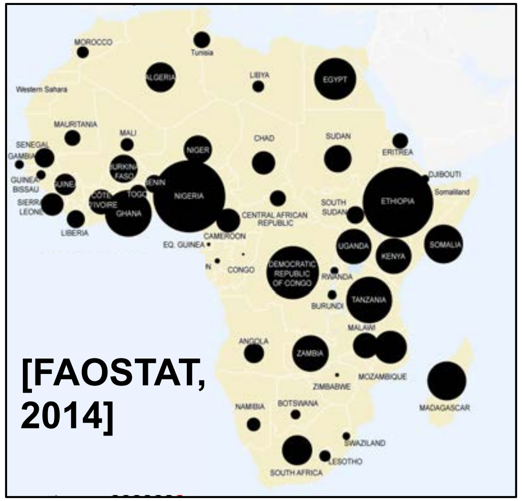
Charcoal production, transport and use emissions for 2014

CO [$10^3$ tonnes] BC [tonnes] $CH_4$ [tonnes]




[Bockarie et al., 2020]

**Charcoal production hotspots**

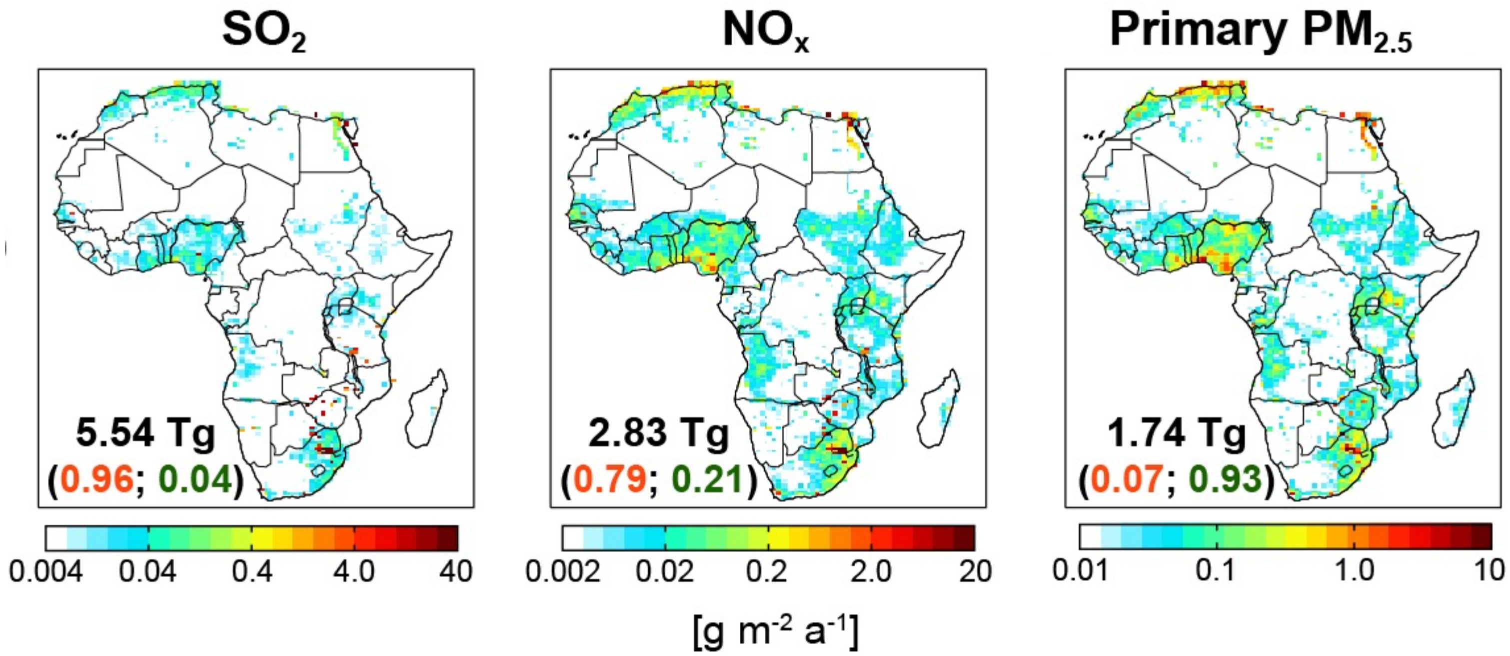



Charcoal industry emissions for Africa 2014 may double by 2030

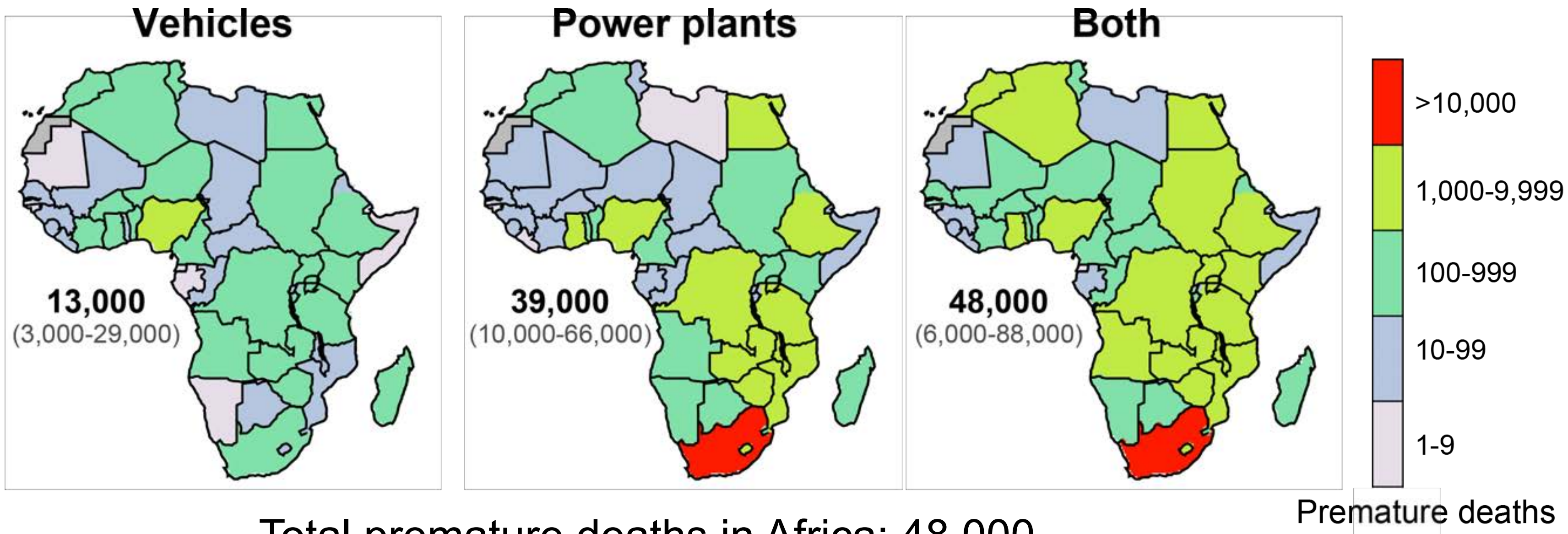
$CH_4$ emissions, specifically, may outcompete those from open fires in West Africa by 2025

# Investment in fossil fuels, despite climate and health impacts

**2030 emissions:**
all vehicles + power plants
(including powerships)

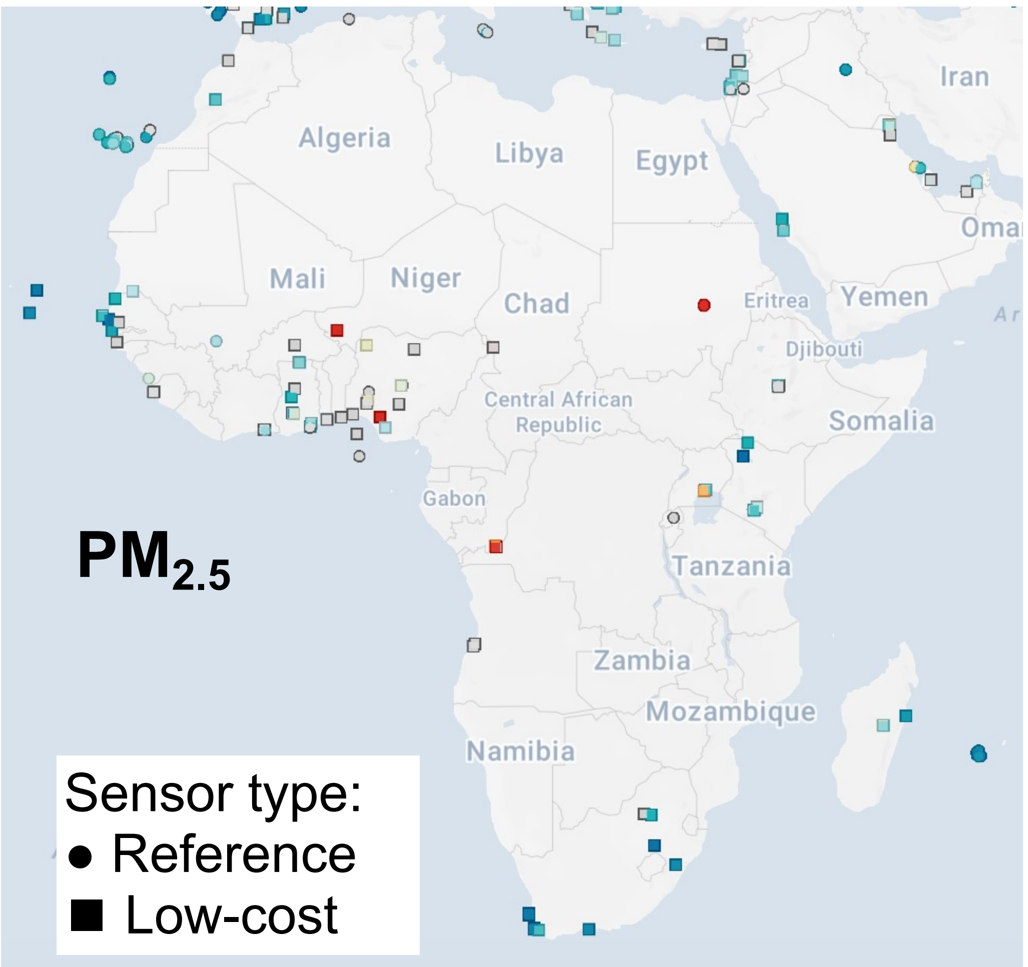




**Premature deaths due to future fossil fuel use:**
GEOS-Chem $PM_{2.5}$ and
Vodonos et al. (2018)
concentration-response curve




Total premature deaths in Africa: 48,000

# Routine monitoring of air quality is sparse





**Maps from OpenAQ.org (28 March 2021)**

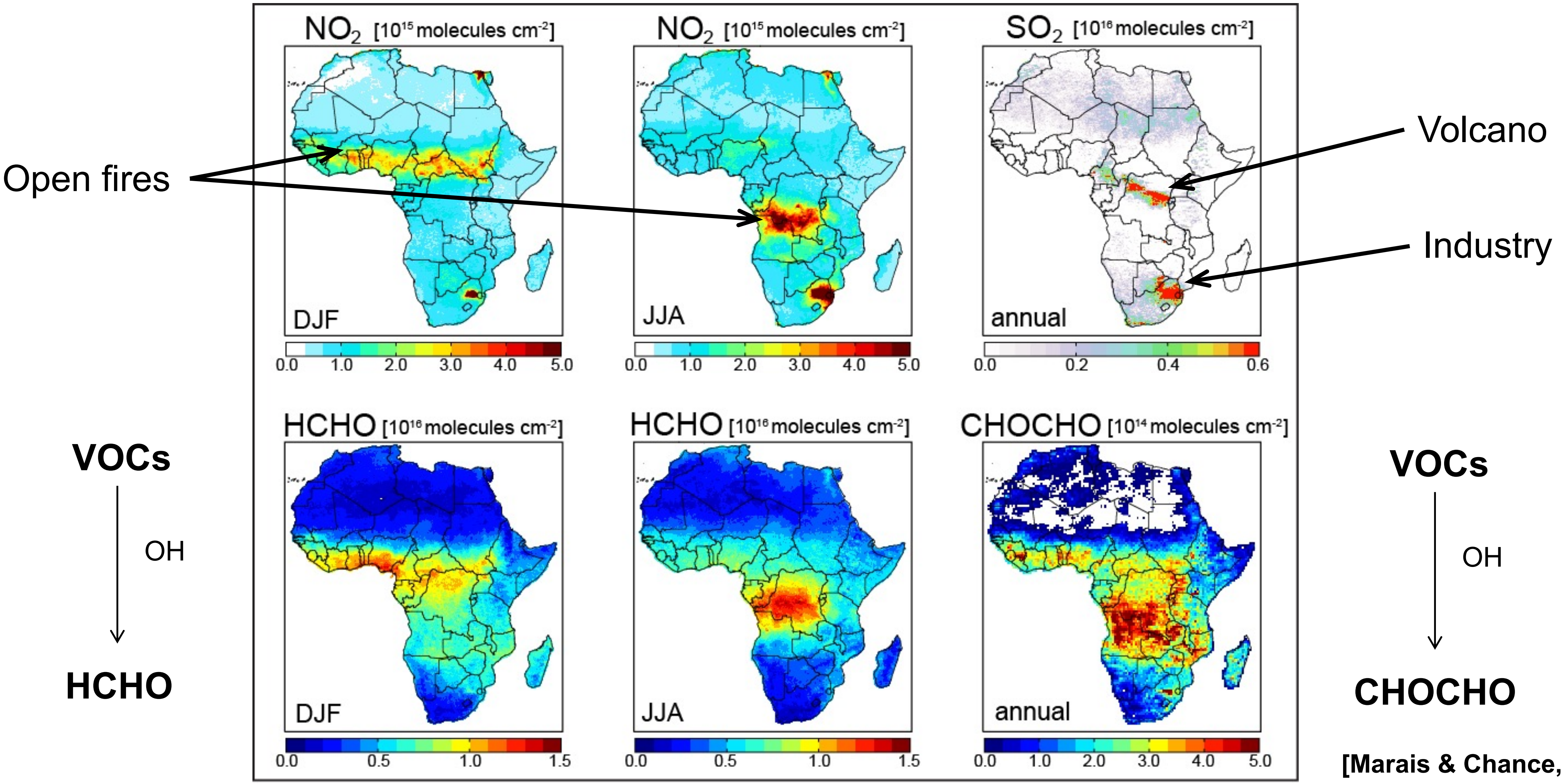
Not all reference monitor data is publicly available and is often susceptible to quality control issues

US Embassy and research institution sites being established in many locations

Deployment of low-cost sensors is helping to fill this gap, but require calibration and validation

# Reliant on satellite observations and models

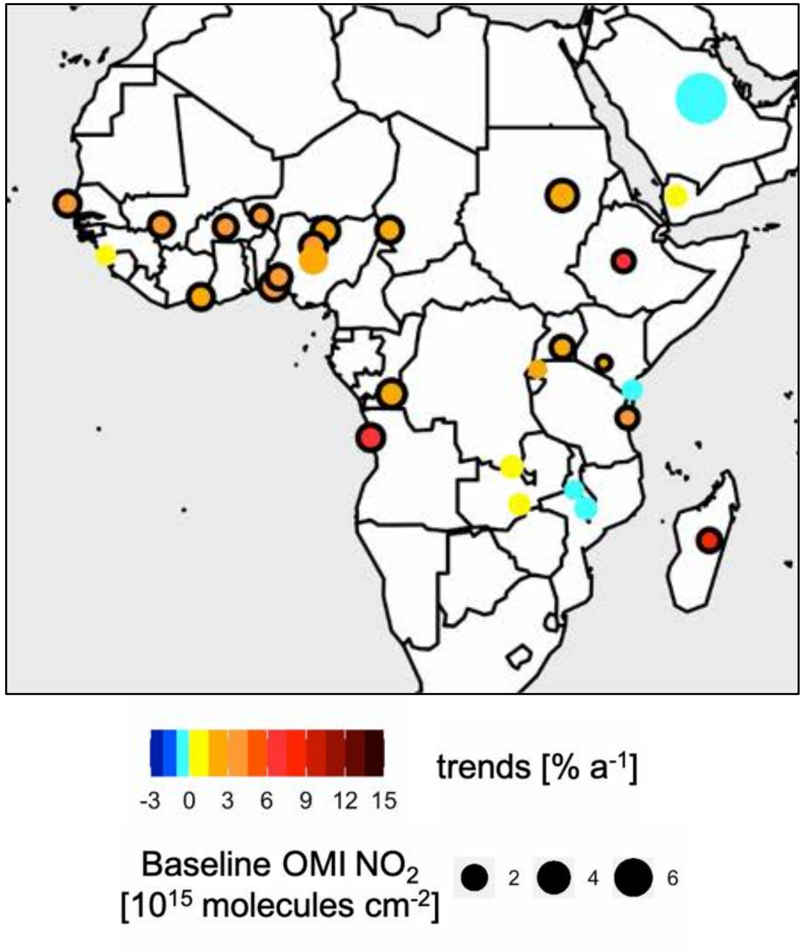
Most space-based instruments provide complete coverage once per day



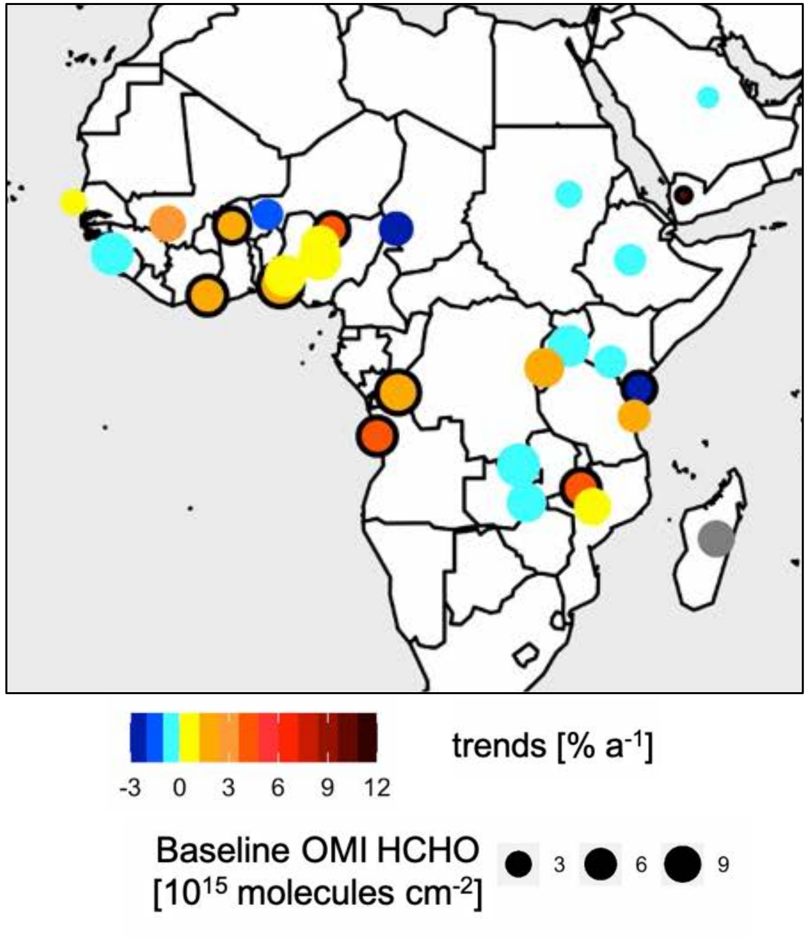

[Marais & Chance, 2015]

# Already evidence of air quality degradation in populous cities

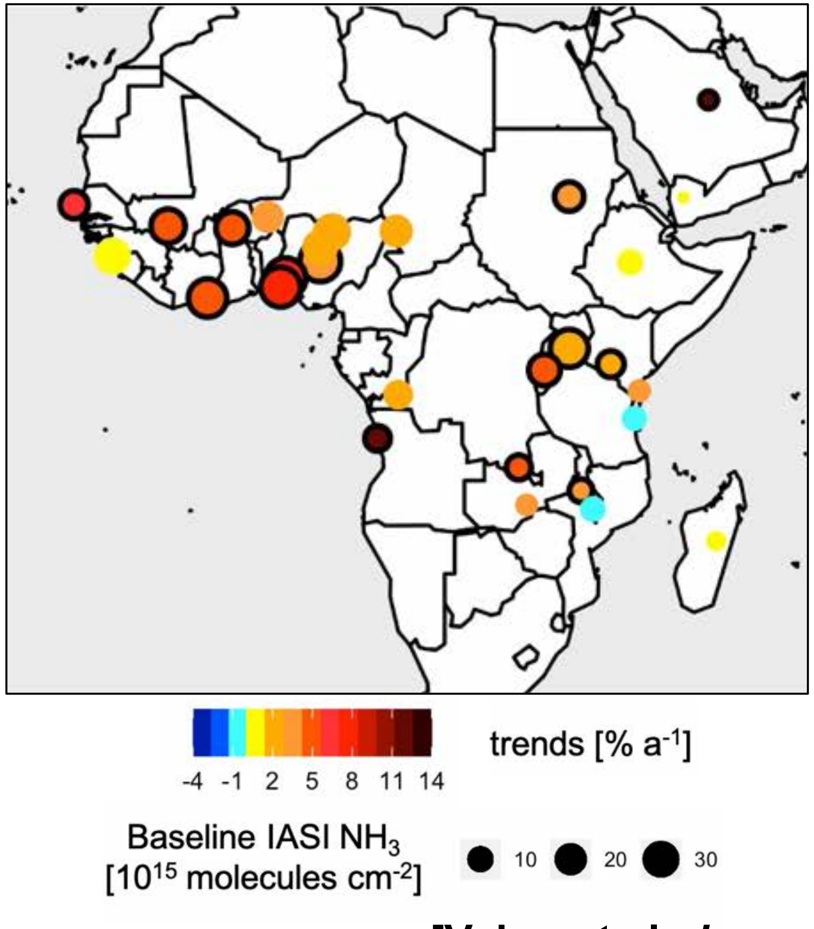
**Trends in OMI $NO_2$ (2005-2018)**




**Trends in OMI HCHO (2005-2018)**
(proxy for NMVOCs)




**Trends in IASI $NH_3$ (2008-2018)**




**[Vohra et al., *in prep*]**

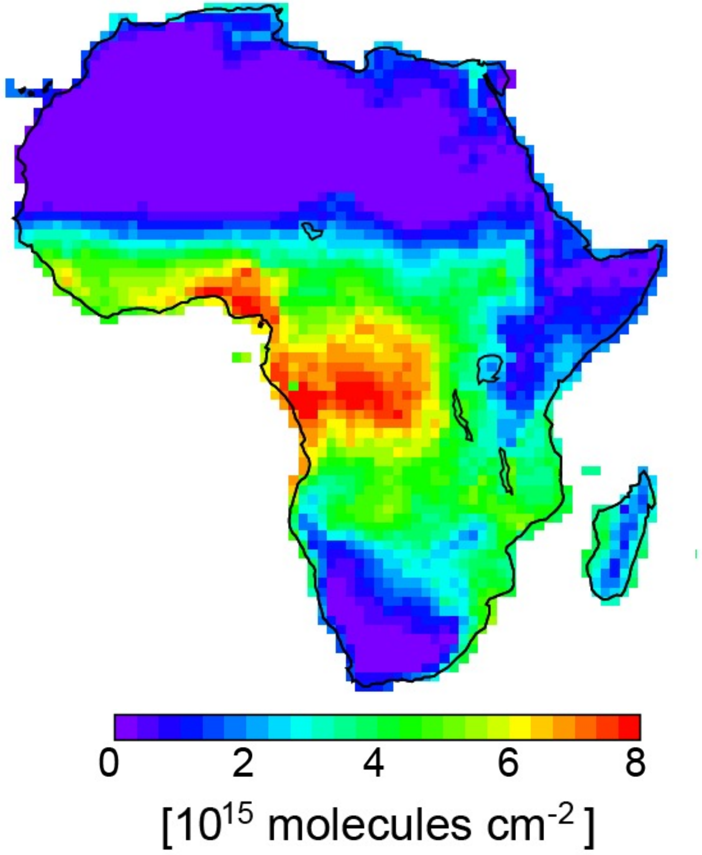
Trends in $NO_2$ greater than those in HCHO. Heading toward VOC-limited ozone formation?

Trends in $NH_3$ possibly from agriculture and burning solid fuels → implications for N mobilization

# Derive and constrain emissions, assess bottom-up inventories

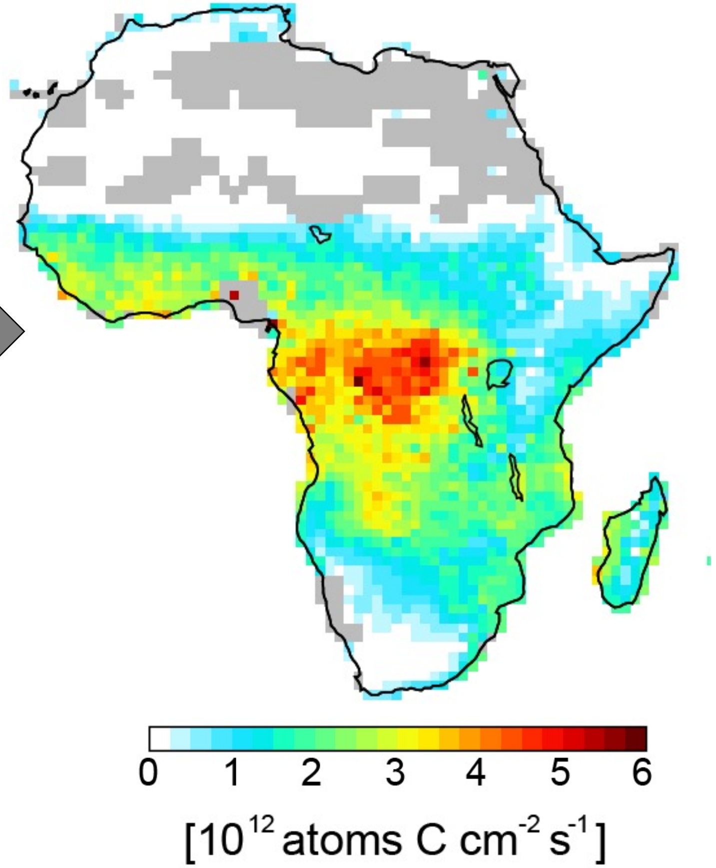
Satellite-derived isoprene emissions from Ozone Monitoring Instrument formaldehyde (HCHO)

Satellite observations of HCHO

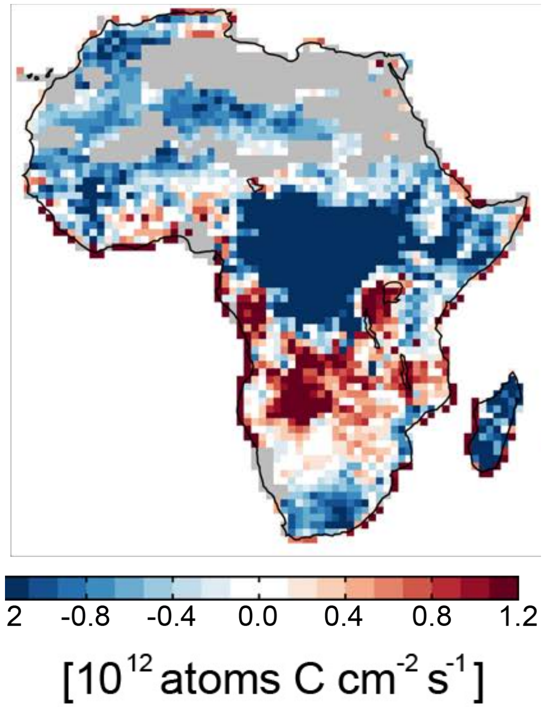



Convert to emissions

Isoprene emissions




Evaluate inventories




Satellite-derived minus inventory emissions

**[Marais et al., ACP, 2012]**

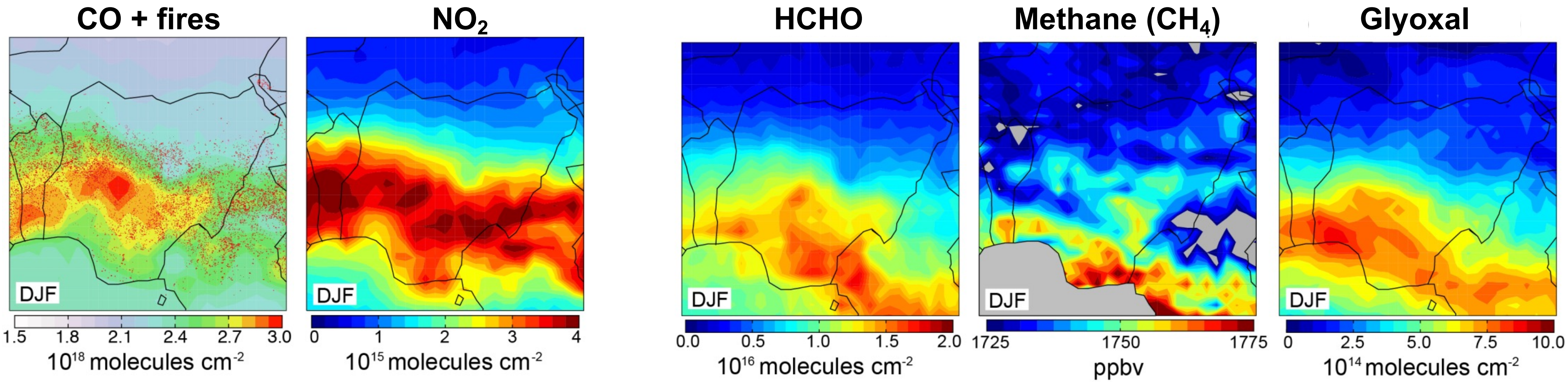
Many other applications: lightning $NO_x$, biomass burning, sources of $NO_x$, $SO_x$, and $NH_3$

Requires surface observations to evaluate satellite observations and derived products

# Characterize sources and conditions that lead to severe air pollution

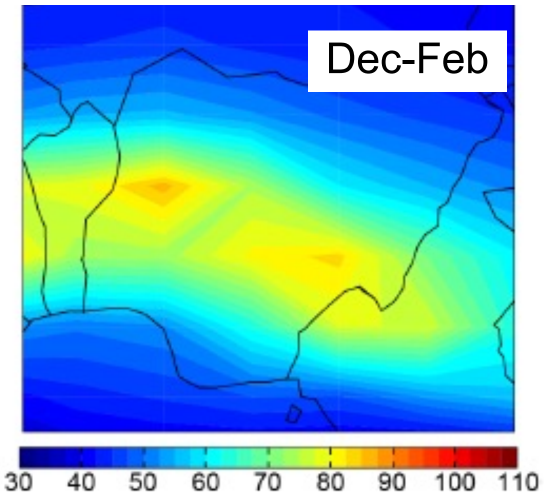
Remote and theoretical constraints on sources (open fires, natural gas leakage and flaring) and dynamics (natural inversion) that lead to severe ozone pollution in Nigeria

**Seasonal open fires** **Anthropogenic Volatile Organic Compounds**




**Seasonal average MDA8 ozone [ppbv] from GEOS-Chem:**

**MDA8:**
Maximum daily average
8-hour surface ozone

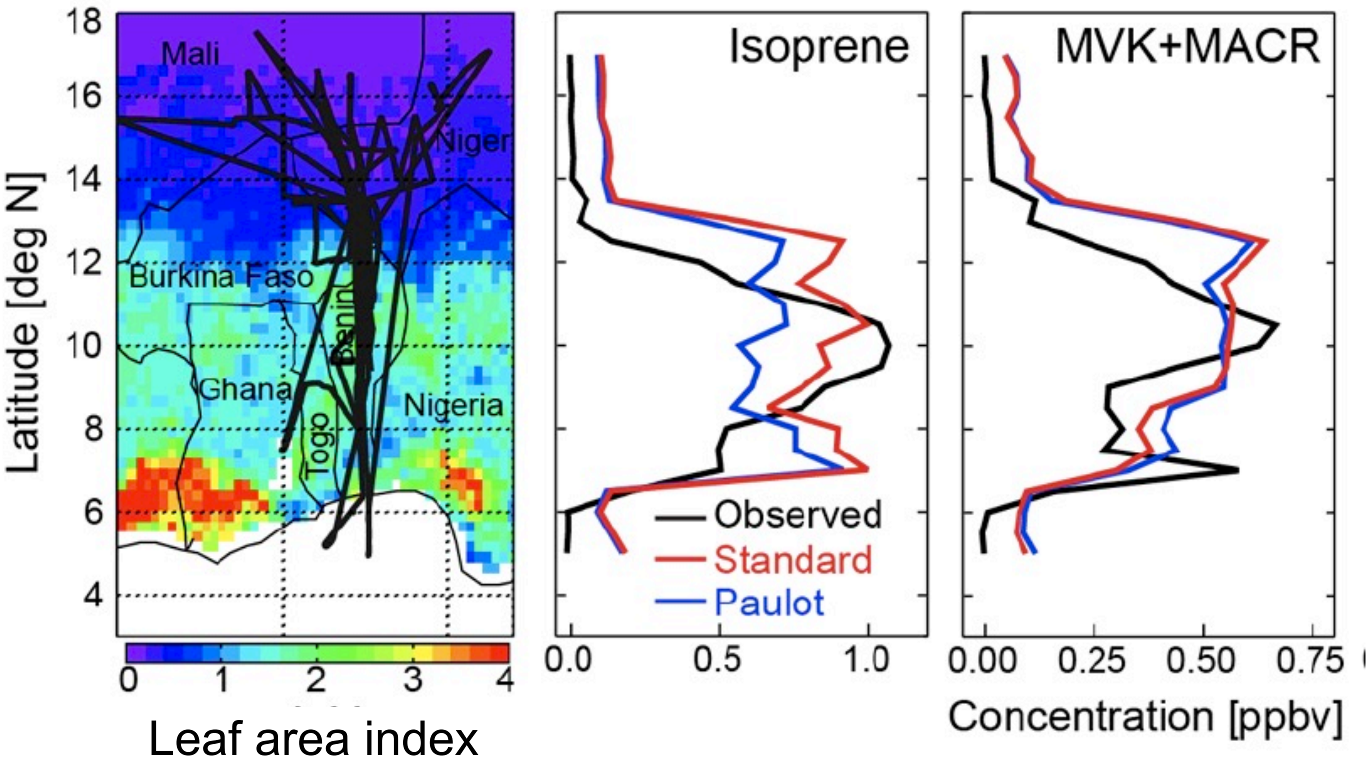



Impact of sources exacerbated by very stagnant natural inversion induced by warm Harmattan winds.

**[Marais et al., 2014]**

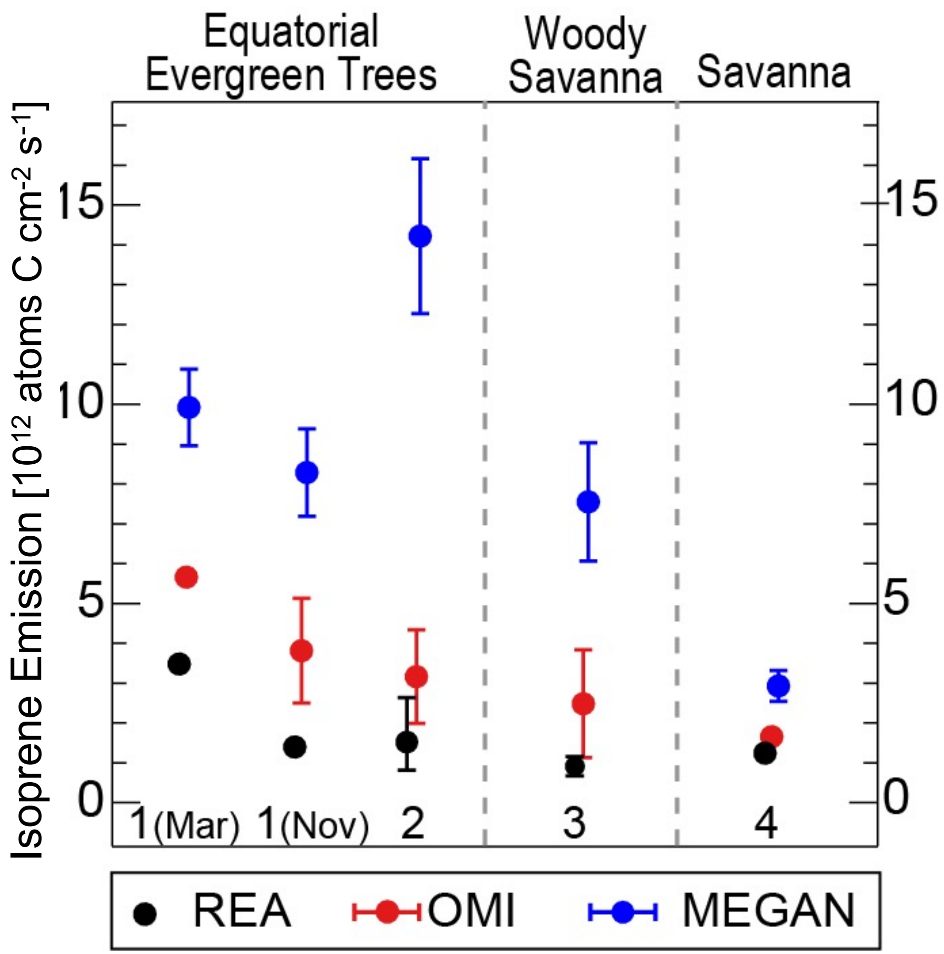
# Field campaigns are vital, but challenging, costly and high-risk

**Assess model chemistry mechanisms during AMMA**




**[Marais et al., 2012]**

**Use historical flux measurements (REA) from EXPRESSO and SAFARI to arbitrate**




**[Marais et al., 2014]**

[Others aircraft campaigns](#):
DECAFE, DACCIWA, CAFÉ-Africa, ATom, ORACLES, IAGOS

[Other networks:](#) AERONET, Pandora/Pandonia, GAW

# What's on the Horizon?

- **Satellites**: Ongoing launches of high-cost instruments by NOAA, NASA, ESA, CNSA and lower-cost instruments by a range of players
- **Health**: Improved monitoring of aerosols with the NASA MAIA mission (2022 launch)
- **Surface monitors**: Increased deployment of low-cost sensors
- **Models**: Enhanced modelling tools that better capture local conditions
- **Local capacity**: Growing capacity at local institutes in Rwanda, Nigeria, Ghana, Kenya, South Africa, Sierra Leone
- **International interest**: Heightened interest in air quality in Africa by international organizations. To name a few: UCL, Columbia, NCAR, York, Oxford, HEI, NCAR, KIT, SEI, CNRS and so on.

# Acknowledgements

**Marais research group members:**

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