Using models and satellite observations to determine the public health burden of rapid air quality degradation in cities in Africa

UCL Atmospheric Composition and Air Quality Research Group

https://maraisresearchgroup.co.uk/

Eloise Marais
e.marais@ucl.ac.uk

Kigali Workshop

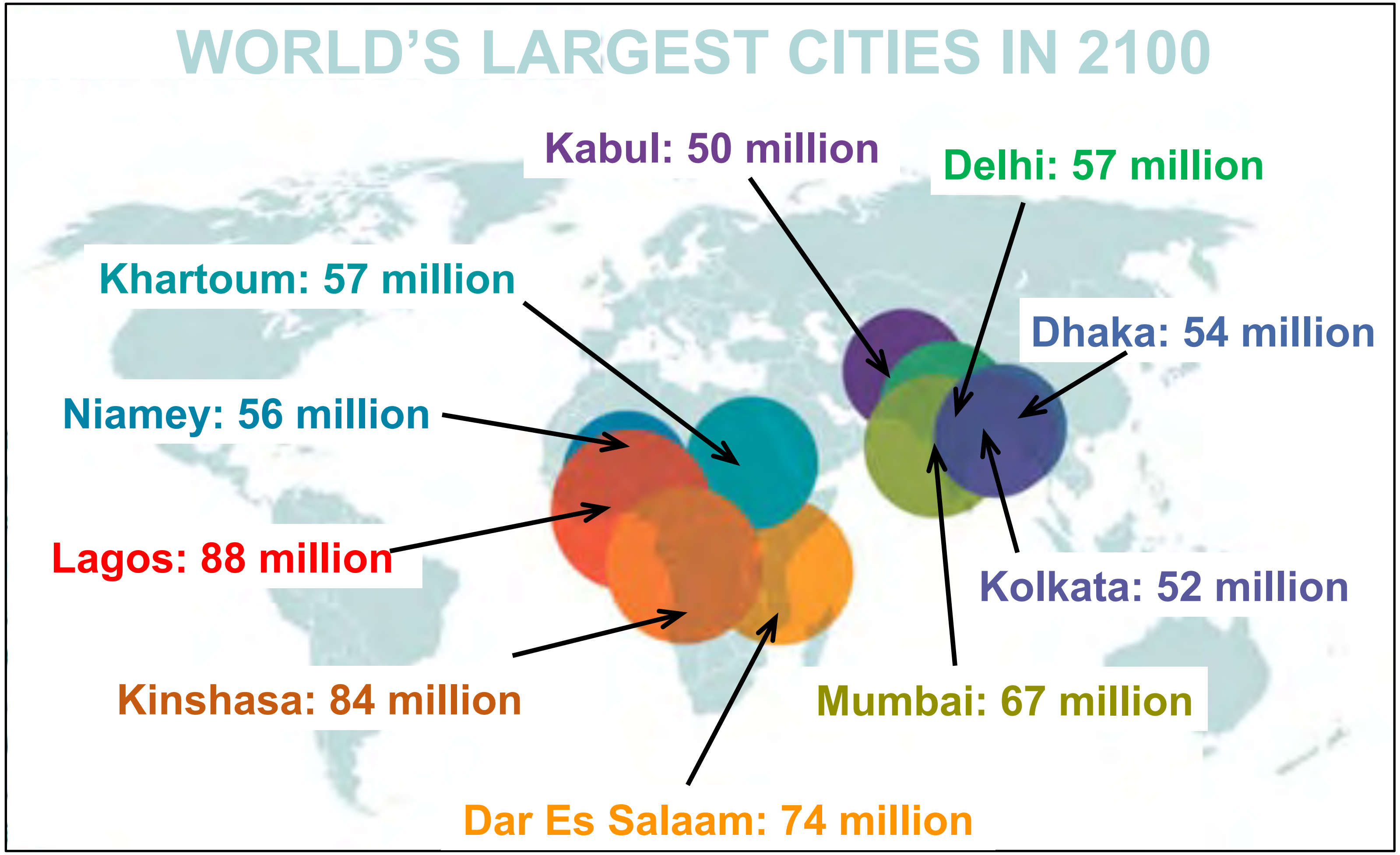
18 January 2023

Fast-growing tropical megacities

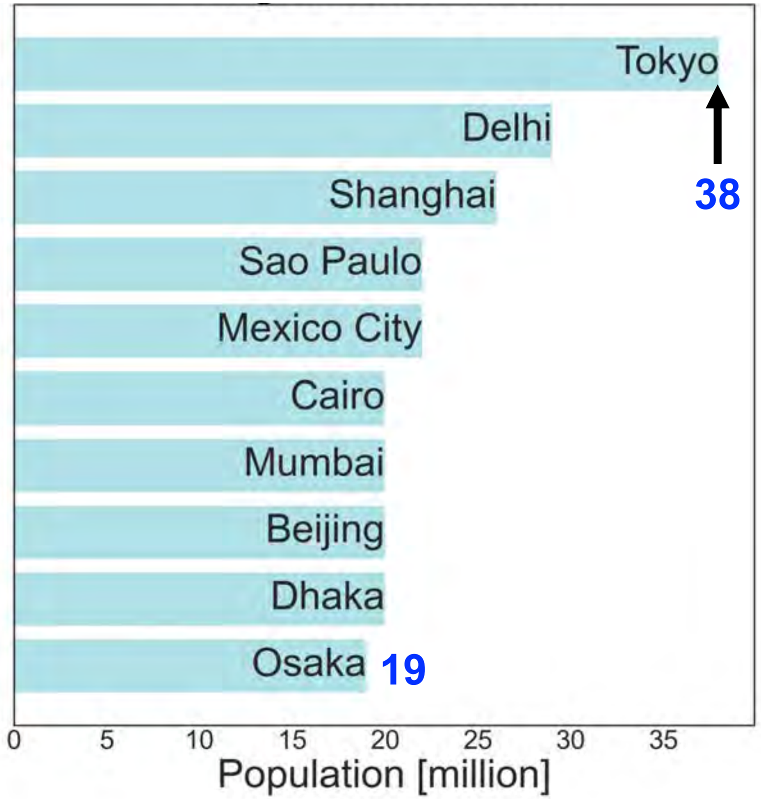
Karn Vohra
postdoc

The largest future megacities are all in the tropics

Mostly in tropical Africa and Asia, where air quality knowledge gaps are largest



Largest cities in 2020



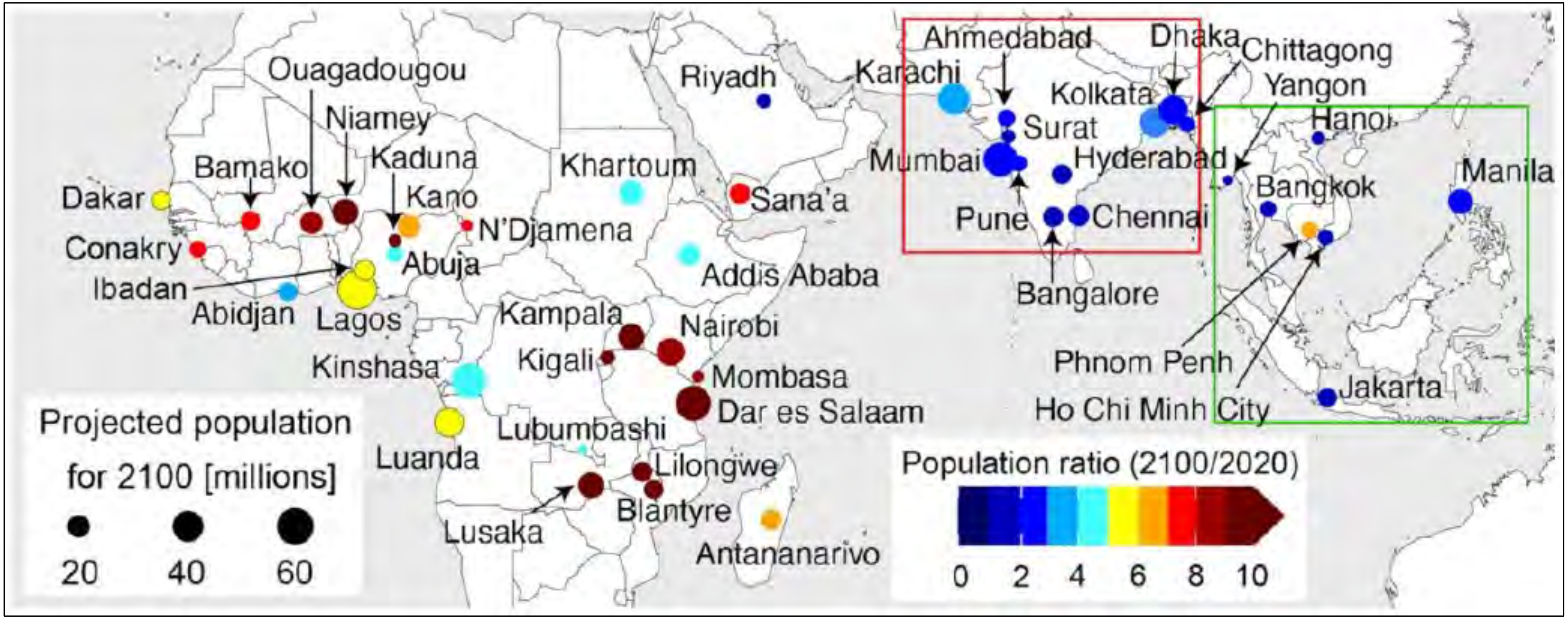
[Image credit: Gongda Lu]

Adapted image: https://medium.com/ensia/here-come-the-megacities-1b0f8a2287f2

Projections: https://journals.sagepub.com/doi/full/10.1177/0956247816663557

Fastest-growing cities are in the tropics

Population growth in the 46 fastest-growing cities in tropical Africa, Asia and the Middle East

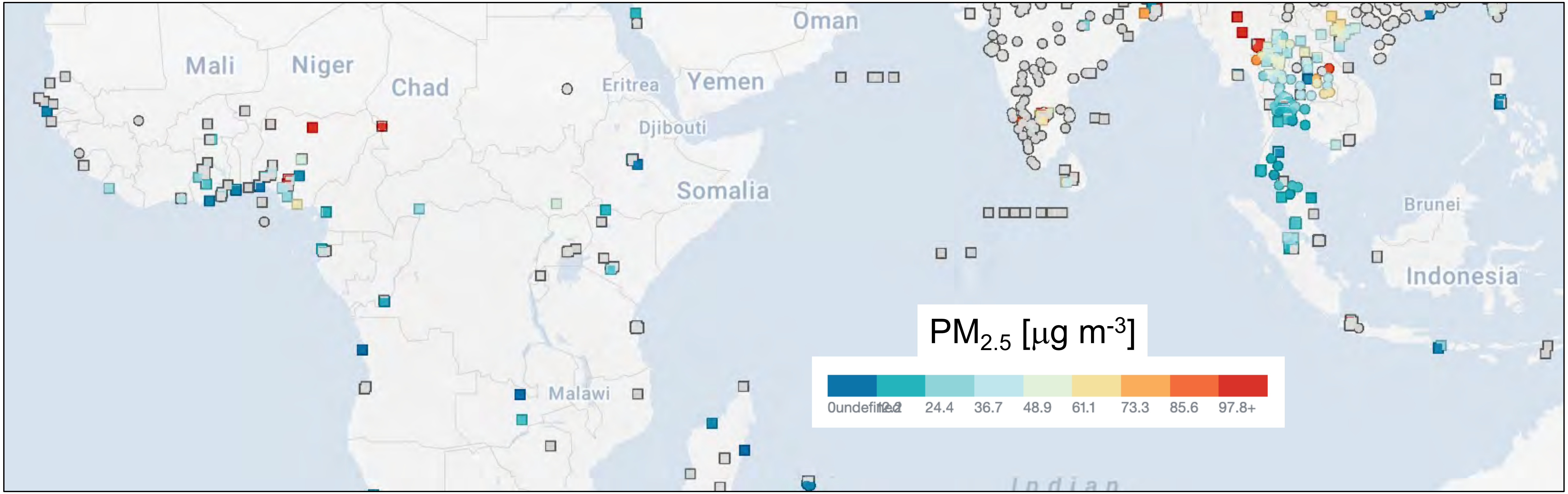


Regional annual projected population growth rates for 2020-2100 [Hoornweg & Pope, 2017]:

3-31% for Africa, 0.8-3% for **South Asia**, 0.5-7% for **Southeast Asia**

Surface monitoring of air pollution severely limited

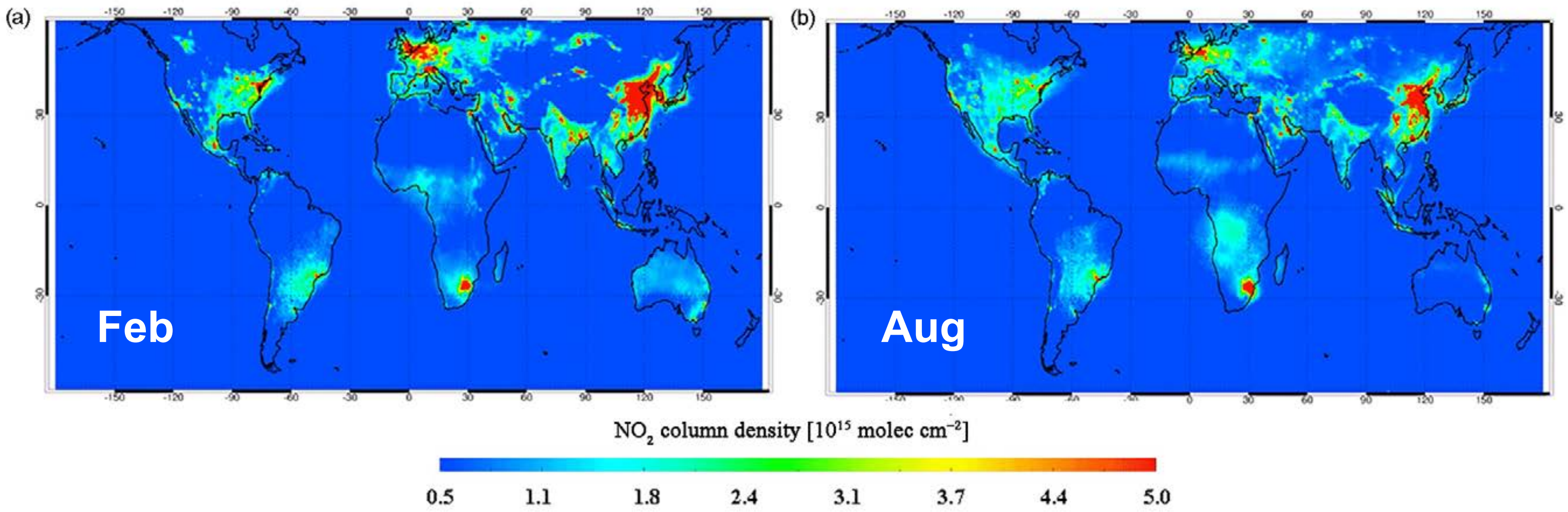
< 1 reference monitor (filled circles) per million people!



Low-cost sensors (squares) helping to address data gaps, but reliability can be an issue

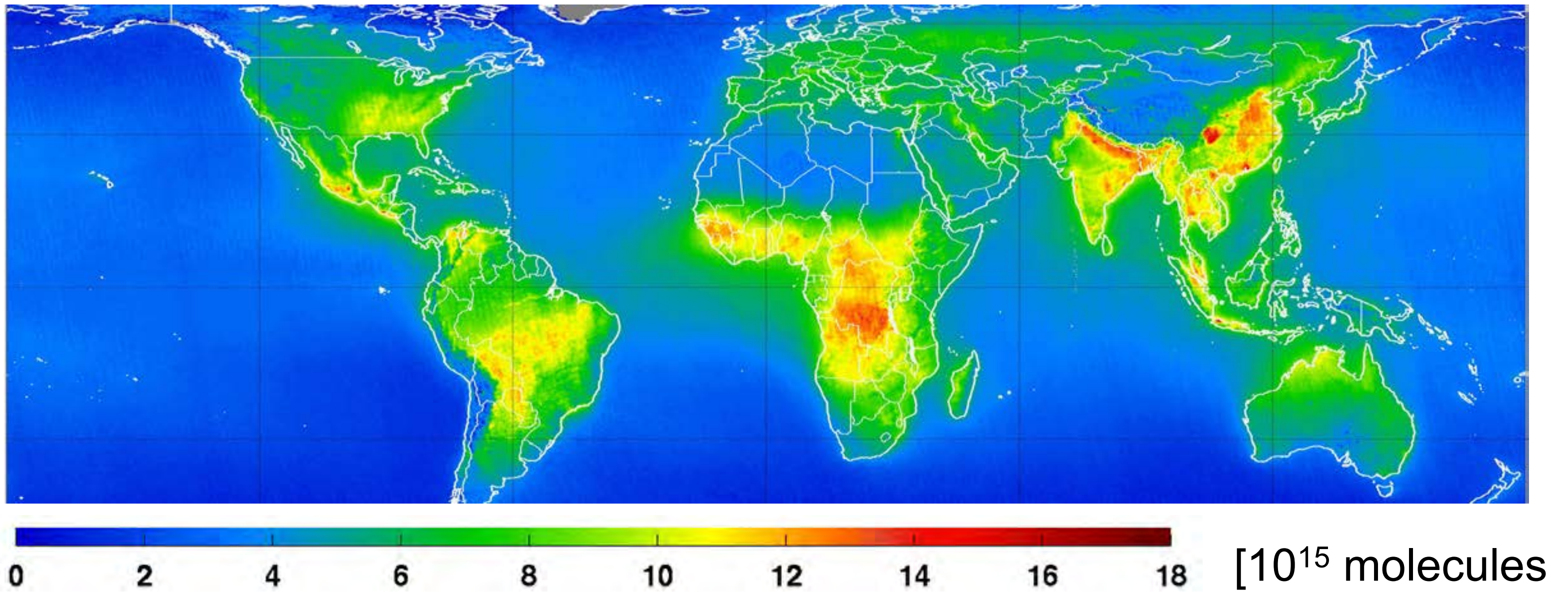
Source: https://openaq.org/#/ (accessed 16 March 2022)

Satellite observations offer global coverage of multiple pollutants



Nitrogen dioxide (NO_2)

Source: Liu et al., 2019

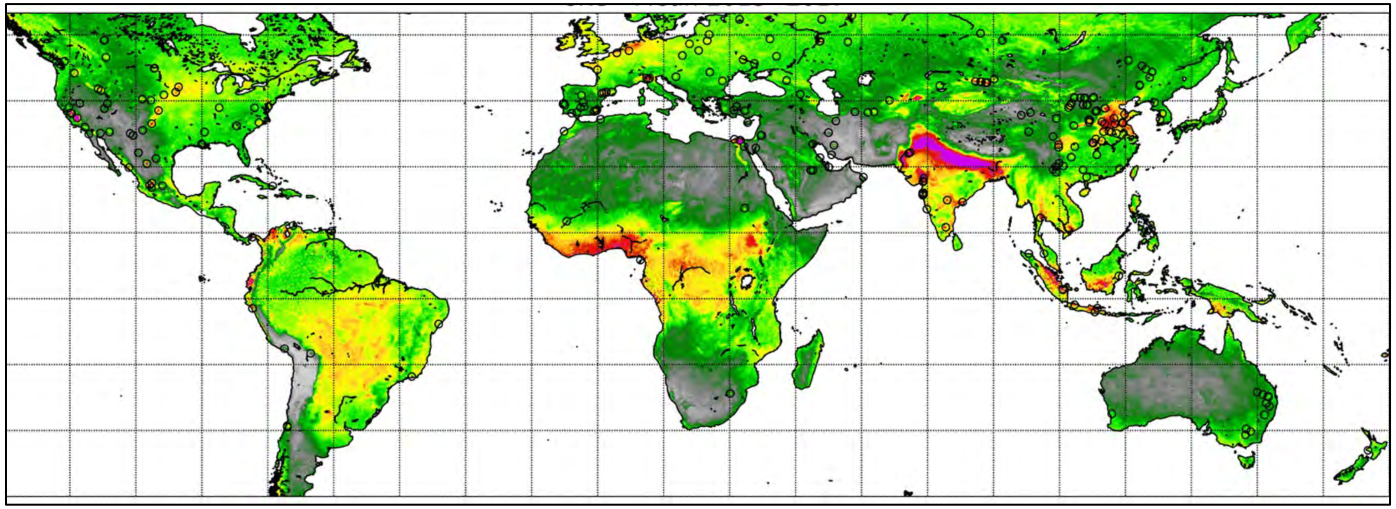


Formaldehyde (HCHO)

Source: De Smedt et al., 2018

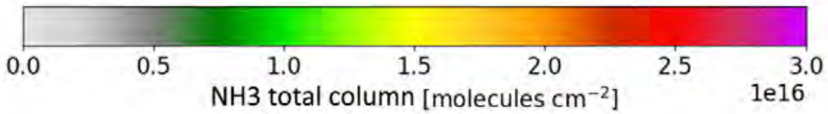
[10^{15} molecules cm^{-2}]

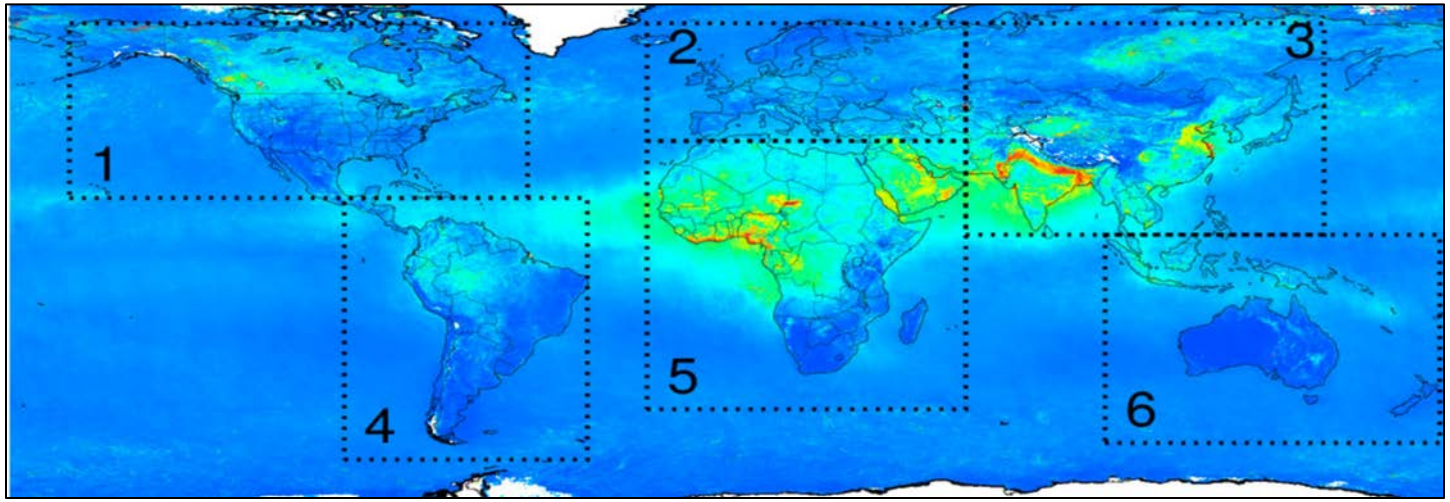
Satellite observations offer global coverage of multiple pollutants



Ammonia (NH_3)

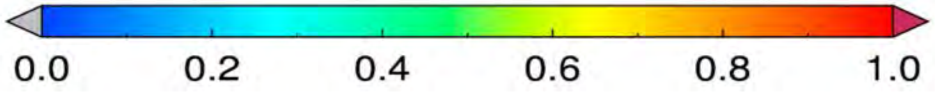
Source: Dammers et al., 2019





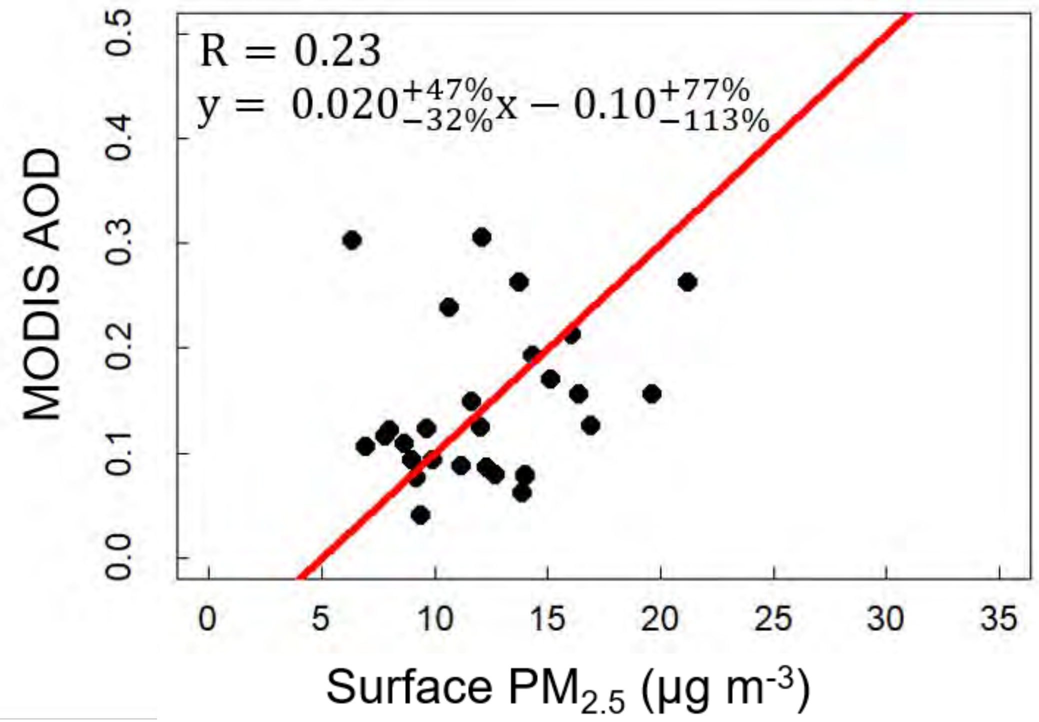
Aerosol Optical Depth (AOD)

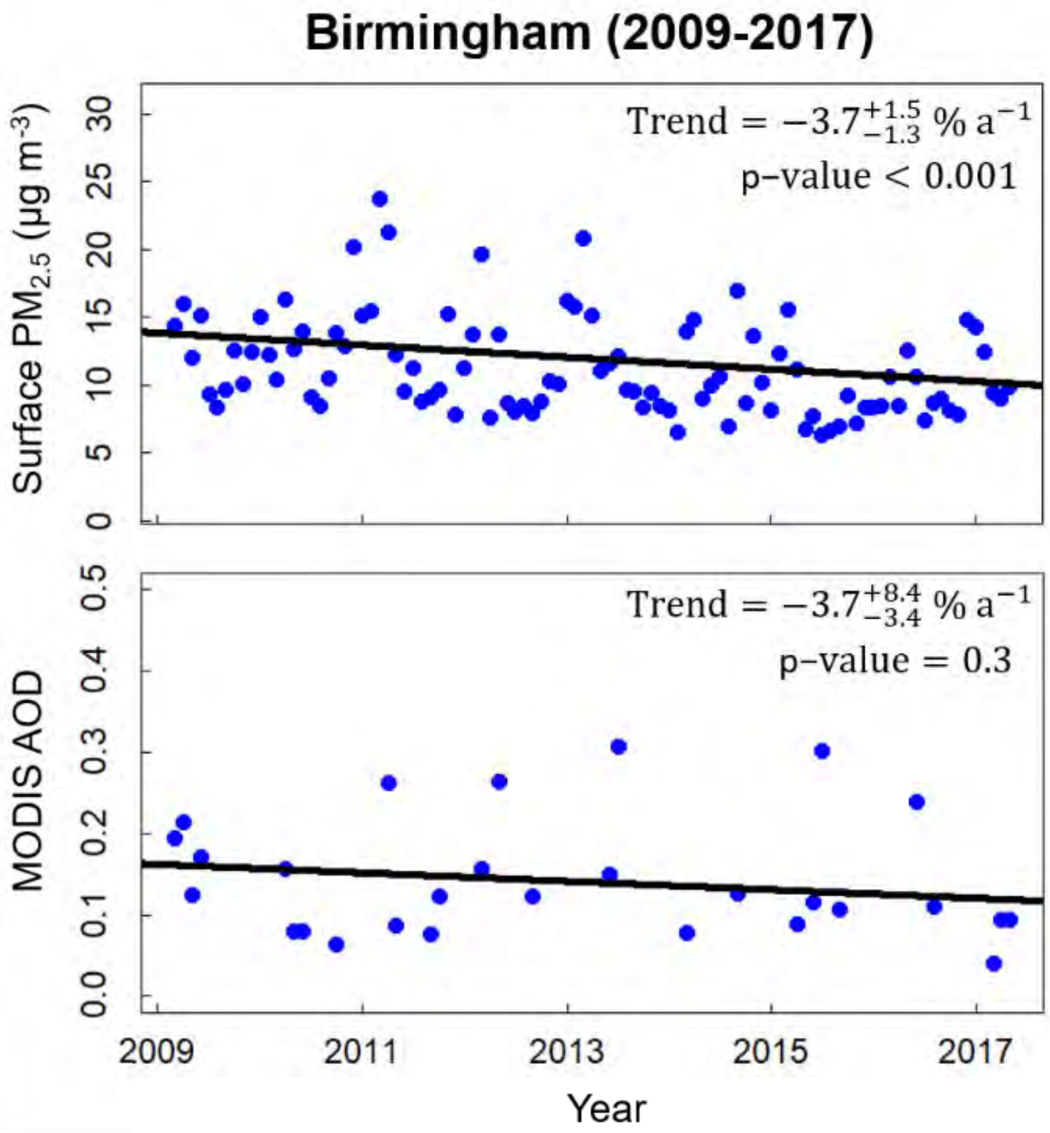
Source: Christopher and Gupta, 2020



Satellite observations of AOD reproduce trends in $PM_{2.5}$

Satellite AOD versus surface $PM_{2.5}$ in **Birmingham**, UK (2009-2017)





Complicated by meteorological conditions, aerosol composition & vertical distribution

[van Donkelaar et al., 2016; Shaddick et al., 2018]

[Vohra et al., *ACP*, 2021]

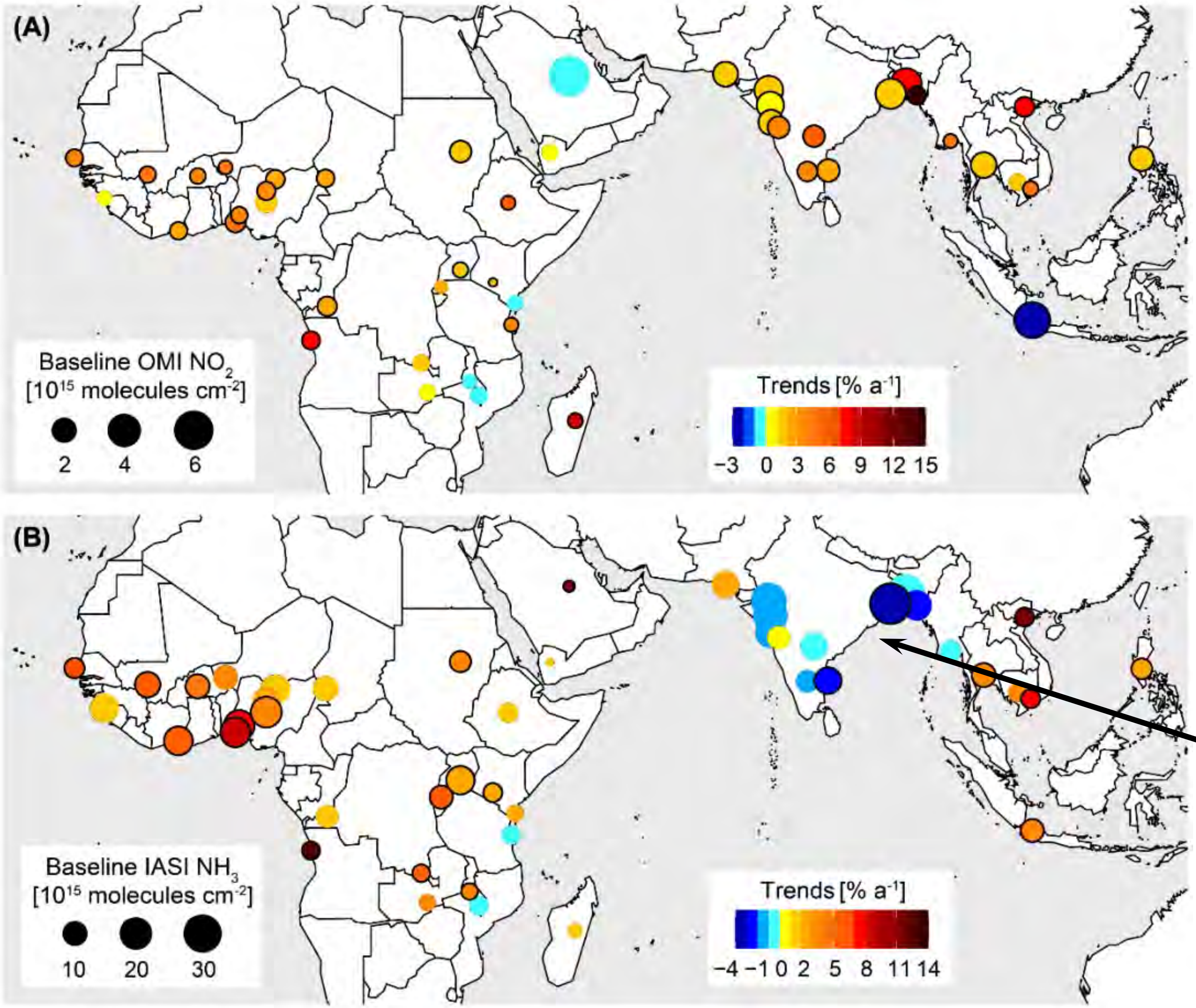
Steep annual increases in NO_x and NH_3

NO_2 trends
(proxy for **NO_x**)
[2005-2018]

OMI: Ozone Monitoring Instrument

NH_3 trends
(depends on acidic aerosol abundance)
[2008-2018]

IASI: Infrared atmospheric sounding interferometer



Circle Features:
Size: start of record
Color: trend
Outline: significant

Decline over Indian subcontinent due to increase in uptake to acidic aerosols

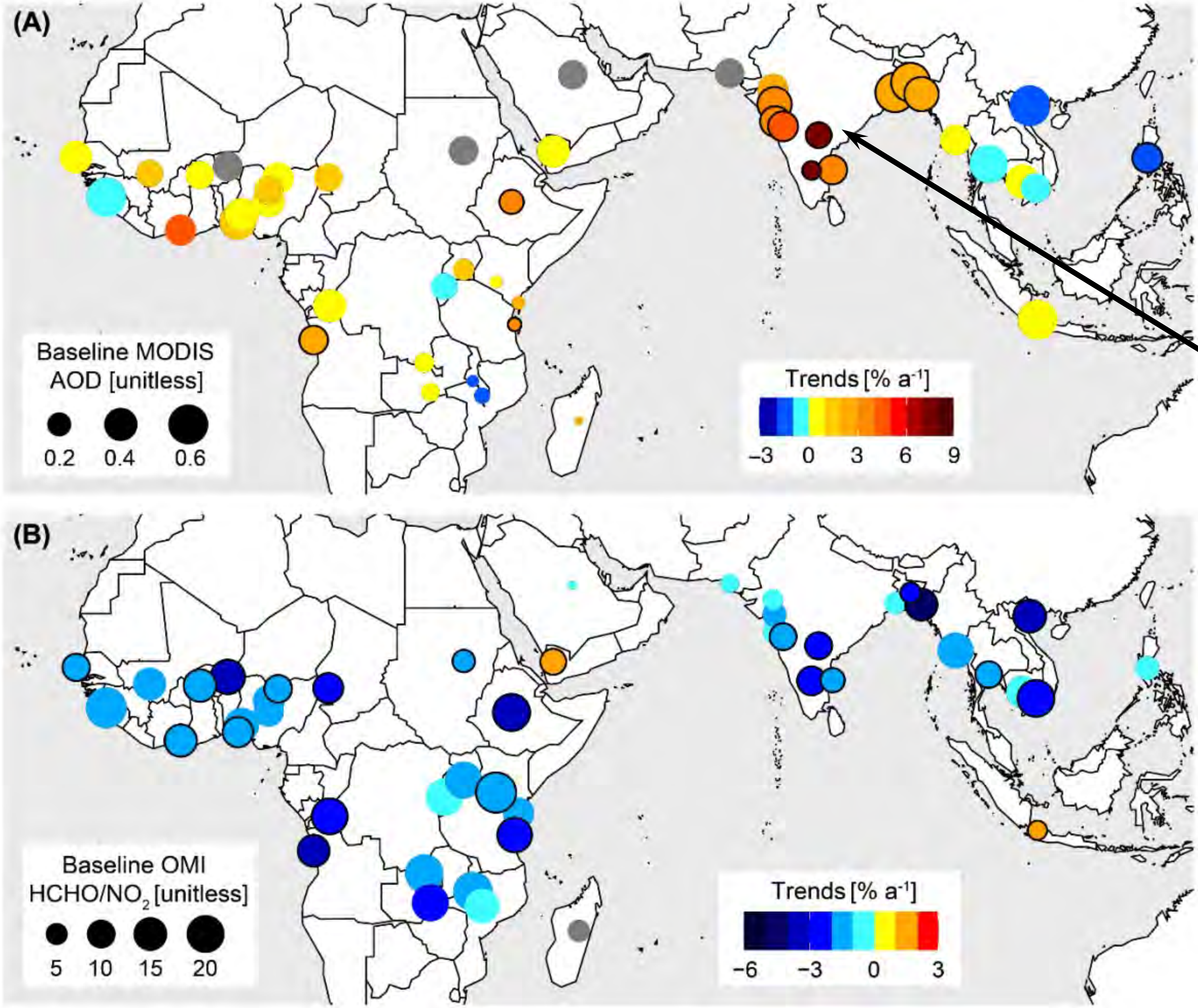
NH_3 data from M. Van Damme, L. Clarisse, P.-F. Coheur at ULB

Annual changes in $PM_{2.5}$ and ozone production regimes

AOD trends
(proxy for $\mathbf{PM_{2.5}}$)
[2005-2018]

MODIS: Moderate resolution imaging spectroradiometer

$HCHO/NO_2$ trends
(proxy for ozone production regime)
[2005-2018]



Circle Features:
Size: start of record
Color: trend
Outline: significant

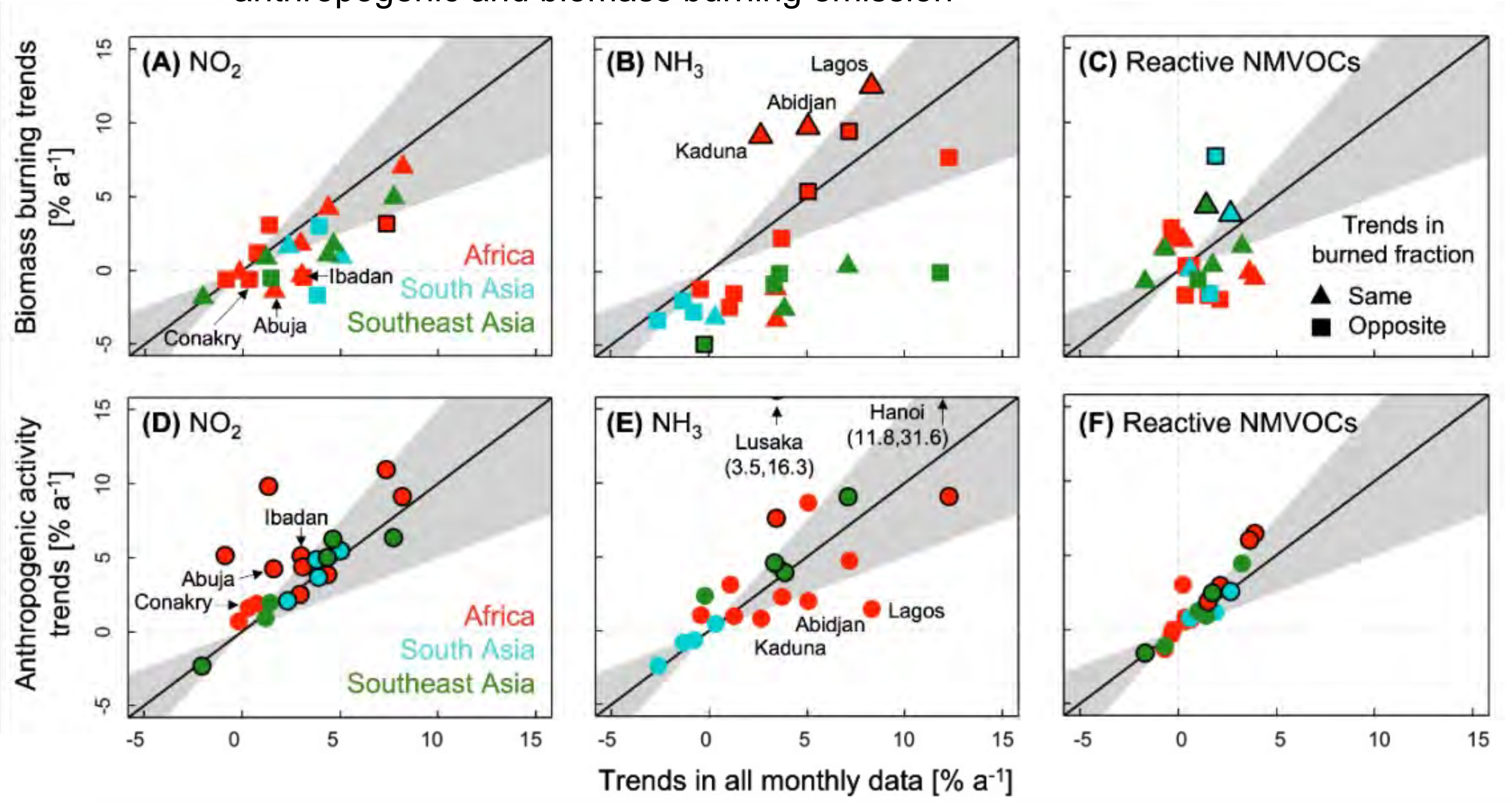
Increases in $PM_{2.5}$ precursors SO_2, NH_3, NO_x

Ratio > 5:
O_3 production sensitive to NO_x

Transitioning to NO_x saturated or VOC sensitive

What's driving the observed trends?

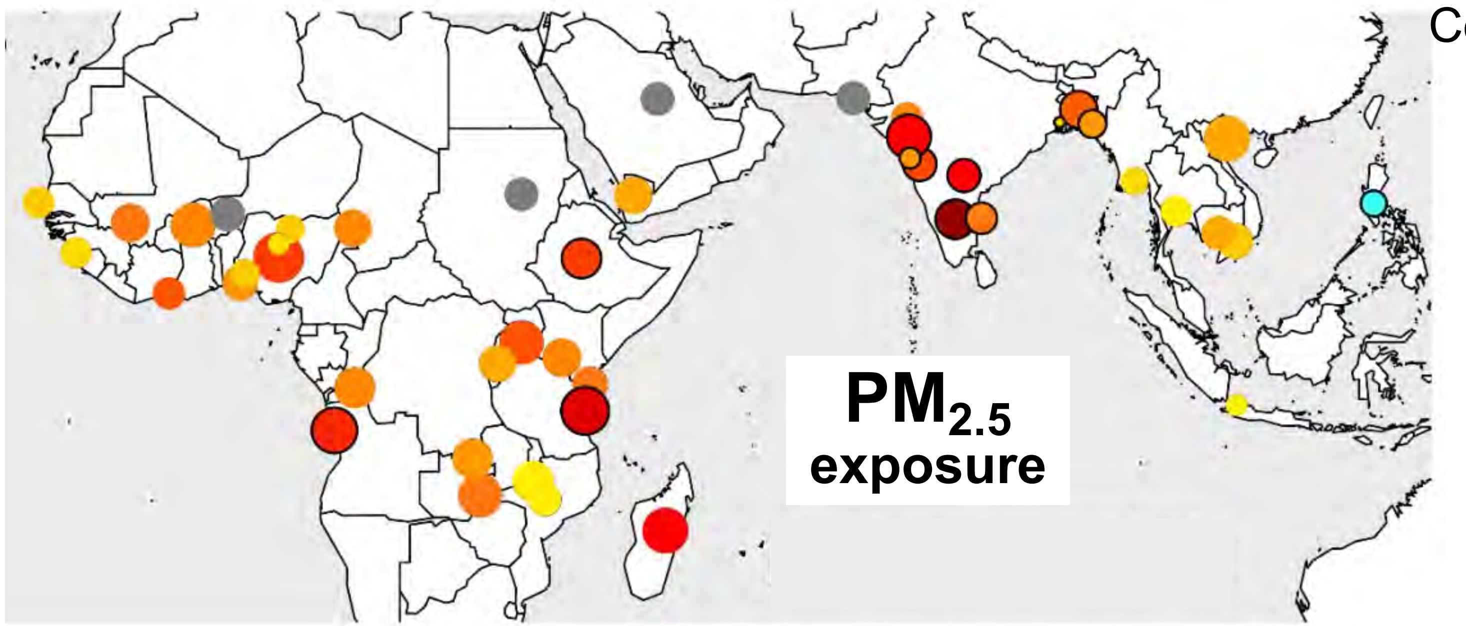
We use a statistical approach and knowledge of seasonality of emissions to assess the relative role of anthropogenic and biomass burning emission



Shift from rural fires to urban sources

Some trend dampening due to decline in agricultural activity

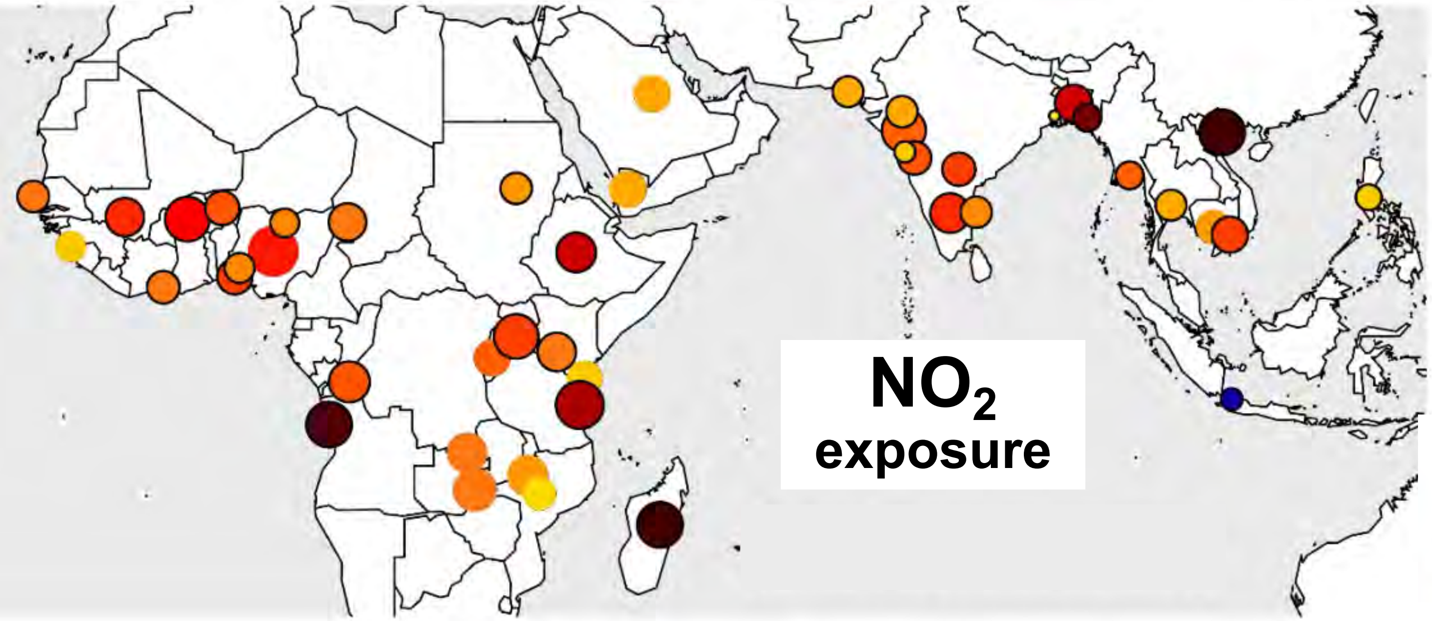
Increase in urban population exposure to air pollution



Combined effect of rapid air quality degradation, increase in population and urbanization

Up to **18 % a^{-1}** increase in $PM_{2.5}$ in India

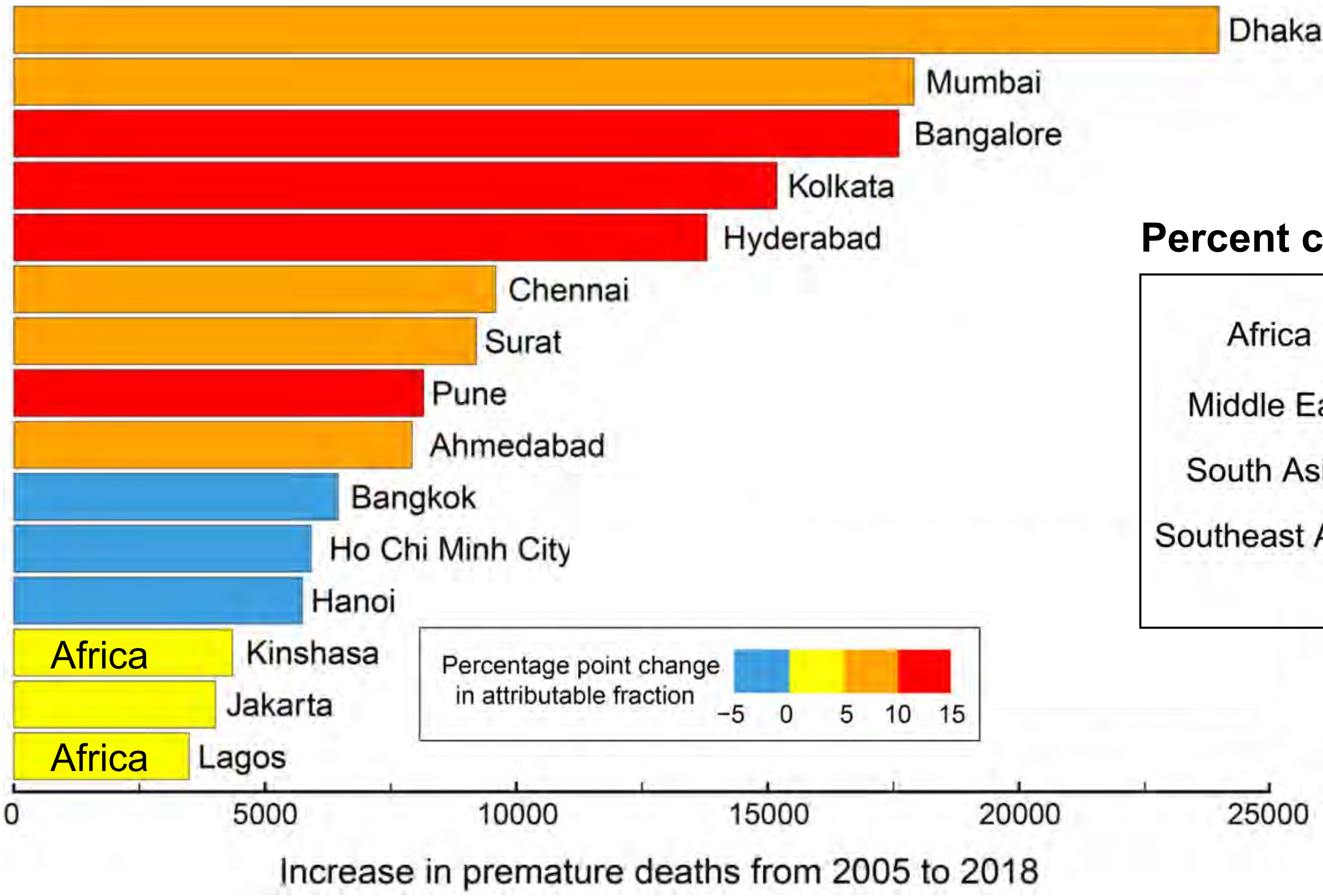
Increased incidence in many health adverse health outcomes leading to premature death



Up to **23% a^{-1}** increase in NO_2 in many cities

Premature mortality attributable to rise in $PM_{2.5}$ exposure

Ranking of cities with greatest health burden

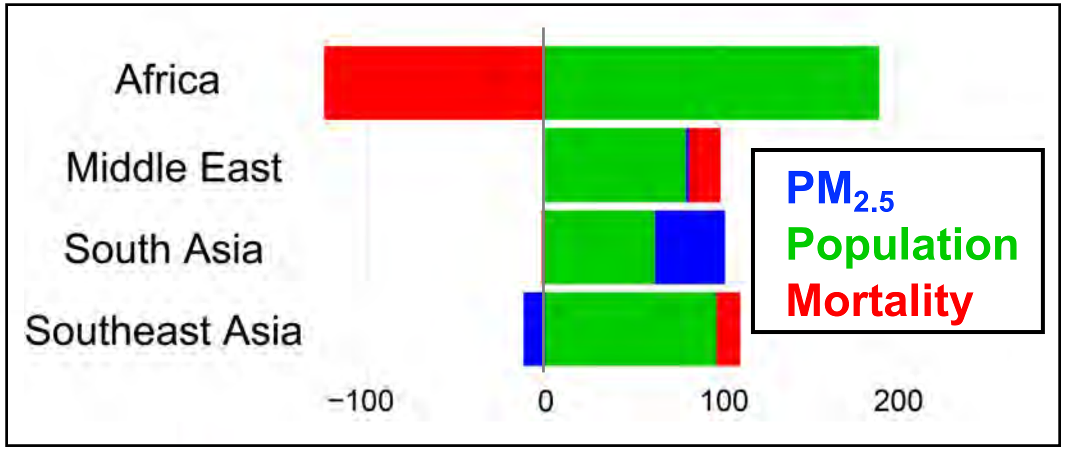


290,000 in 2005

62% ▲

470,000 in 2018

Percent contribution of individual factors



Total: 179,550

[95% CI: -227,131 to 586,231]

Highest ranked are almost all in Asia. Worst effects in Africa buffered by improvements in healthcare.

Take-homes and additional findings from this work

Shift in dominance from traditional (rural fires) to a mix of urban anthropogenic sources

Trends in cities opposite to national and regional trends in Africa

Inventories underestimate growth in precursor emissions suggested by trends from satellite observations

Ozone production transitioning to dependence on volatile organic compounds that are more challenging than NO_x to regulate

Health impacts in cities in Asia likely to occur in cities in Africa in the next 2-3 decades

Link to paper: https://www.science.org/doi/reader/10.1126/sciadv.abm4435

Link to NYT article: https://www.nytimes.com/2022/04/08/climate/air-pollution-cities-tropics.html

Link to The Conversation piece: https://theconversation.com/air-pollution-in-fast-growing-african-cities-presents-a-risk-of-premature-death-183944