

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





# Fast-growing tropical megacities



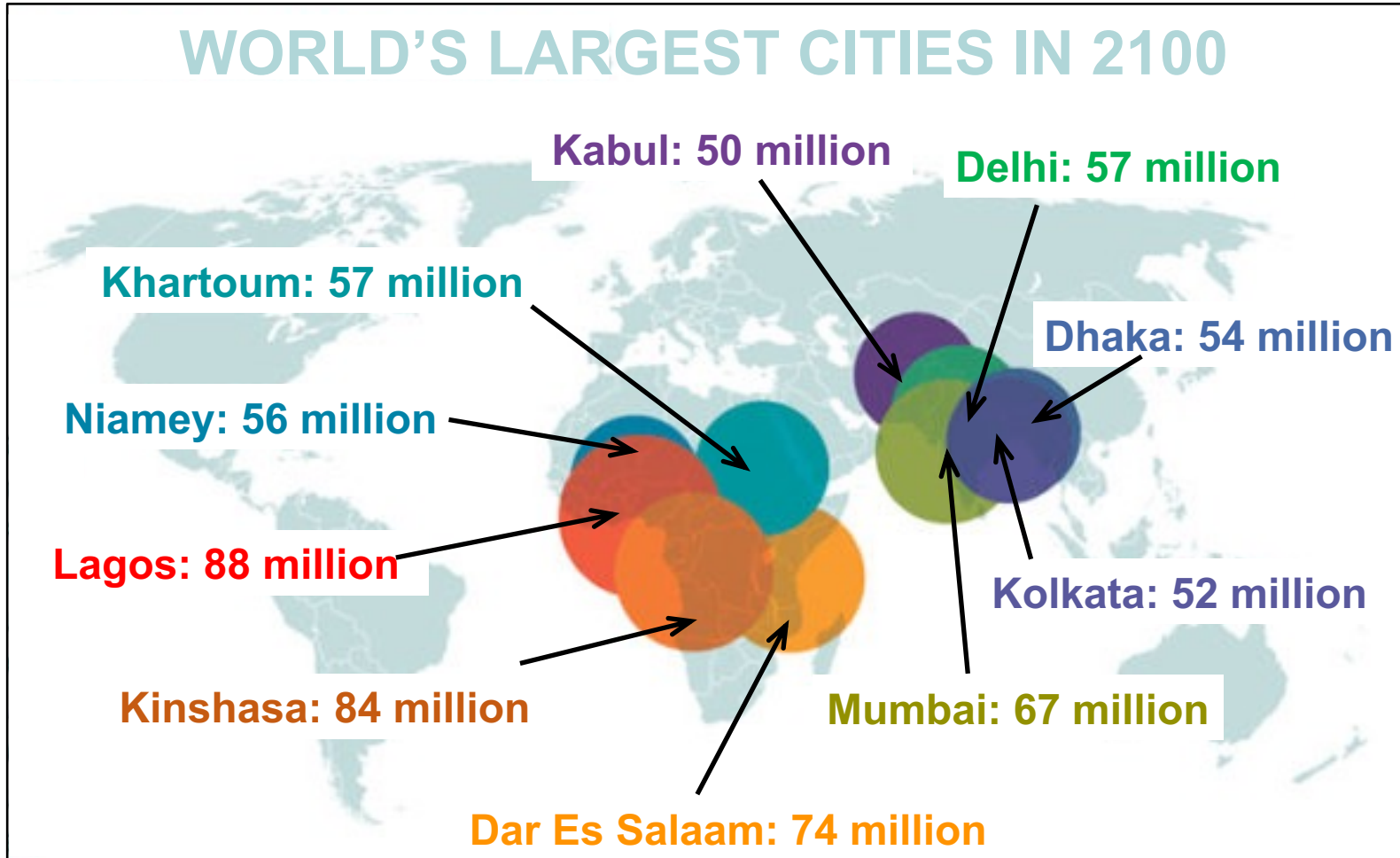
**Karn Vohra**  
postdoc



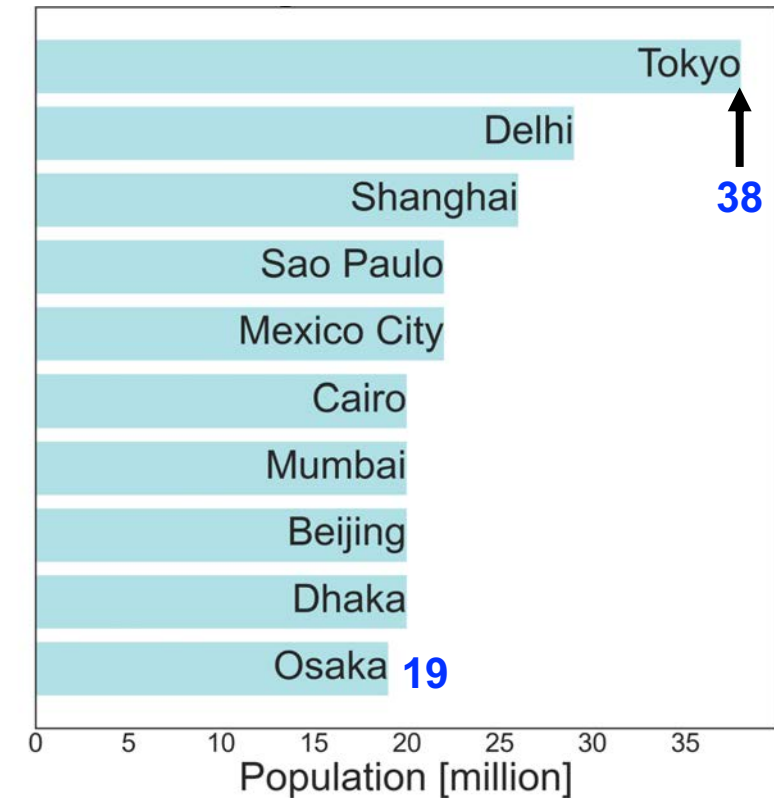
# The largest future megacities are all in the tropics

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

## WORLD'S LARGEST CITIES IN 2100



## Largest cities in 2020



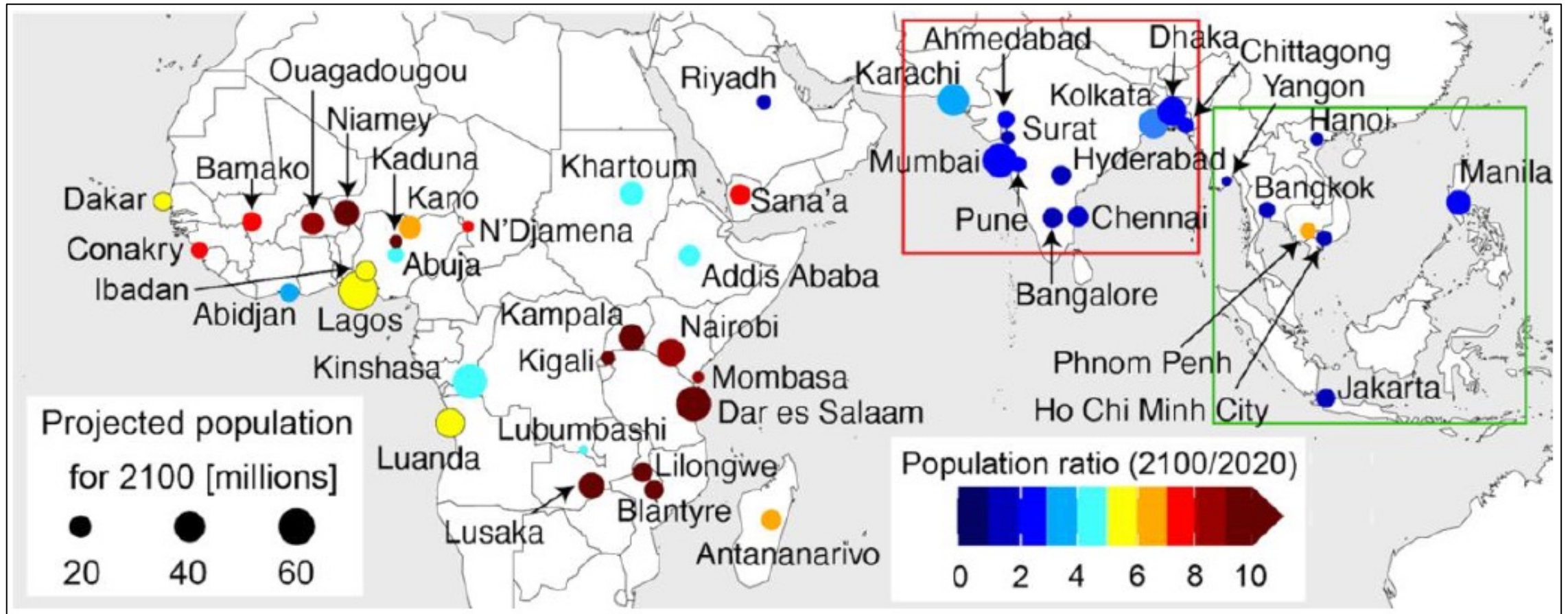
[Image credit: Gongda Lu]

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

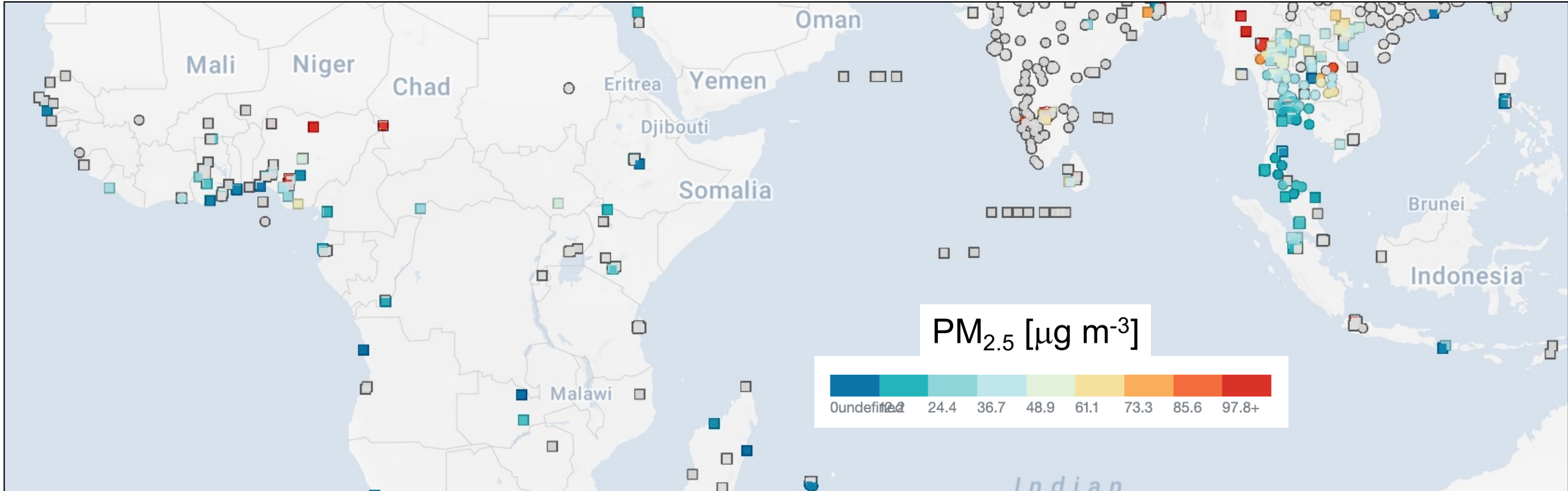


Regional annual projected population growth rates for 2020-2100 [Hoornweg & Pope, 2017]:

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!

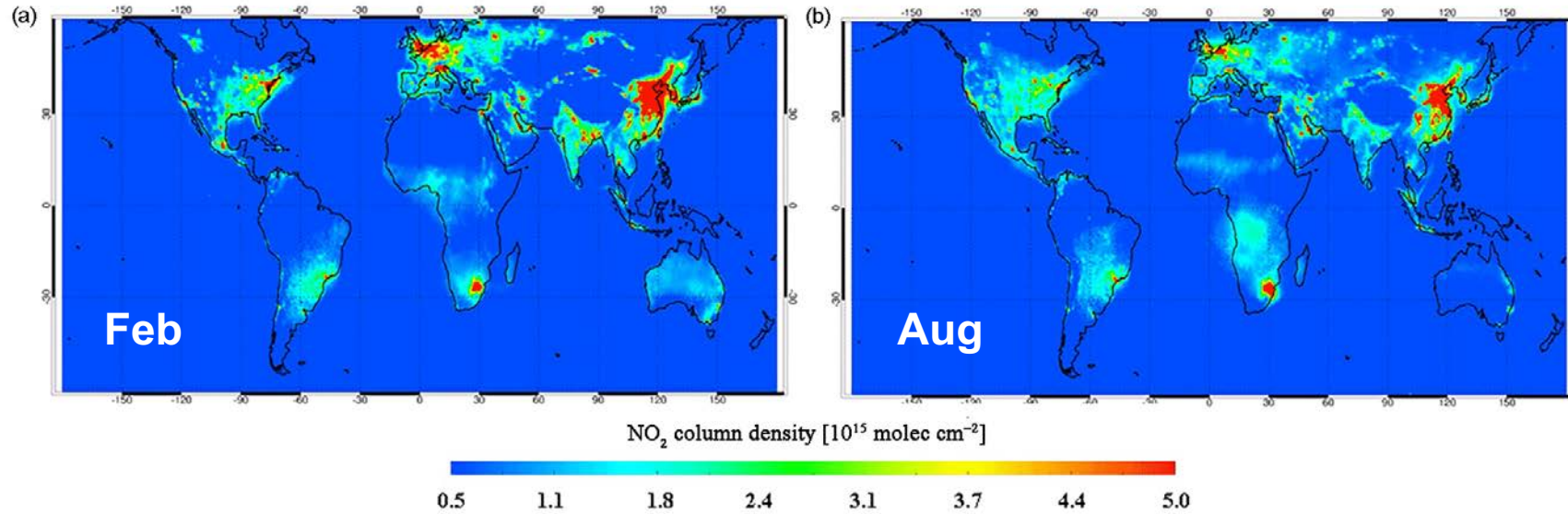


Low-cost sensors (squares) helping to address data gaps, but reliability can be an issue

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

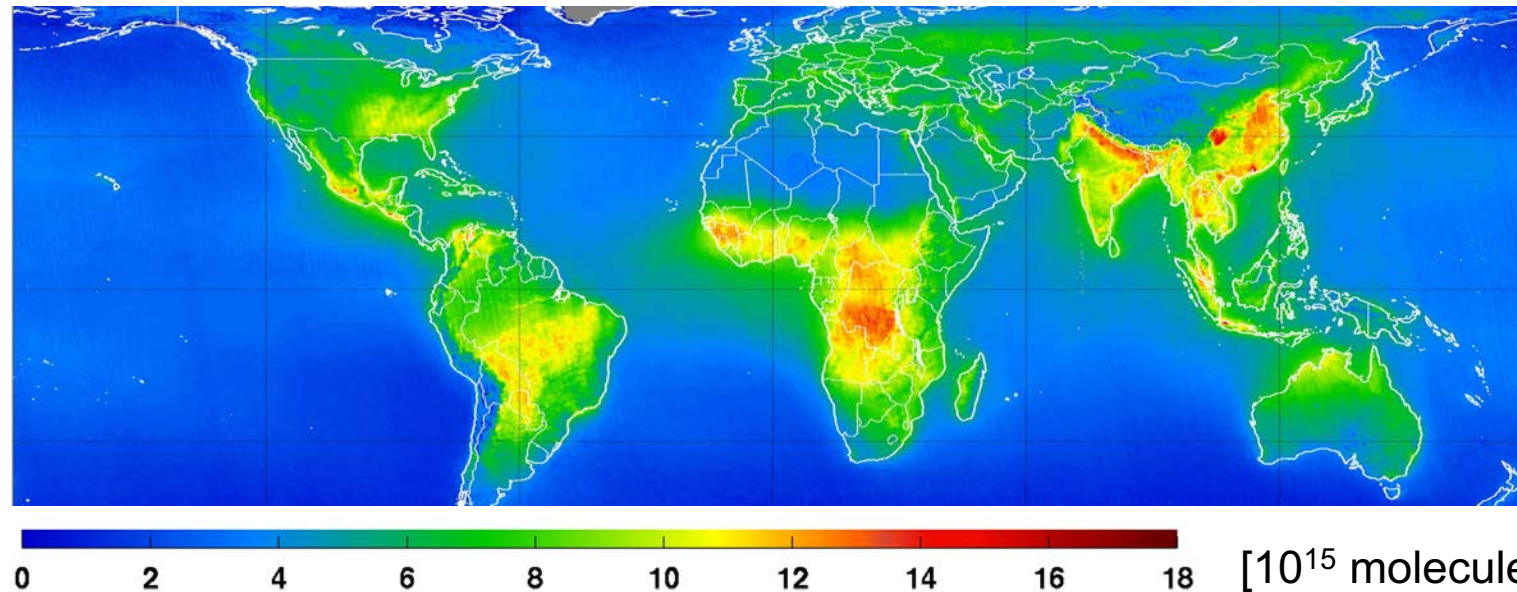


# Satellite observations offer global coverage of multiple pollutants



**Nitrogen dioxide ( $\text{NO}_2$ )**

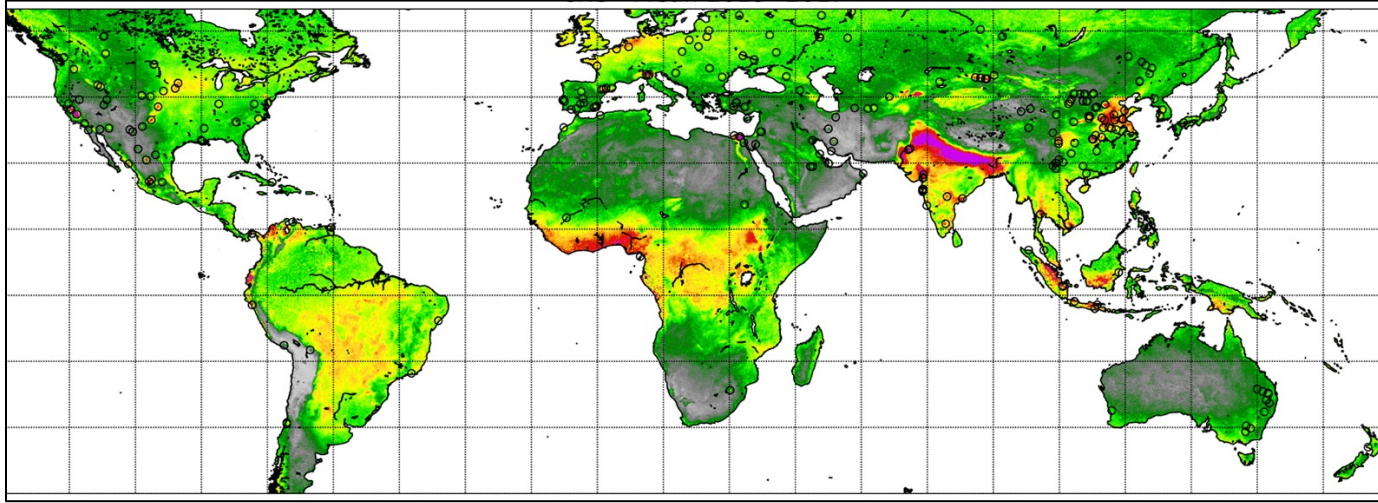
Source: Liu et al., 2019



**Formaldehyde ( $\text{HCHO}$ )**

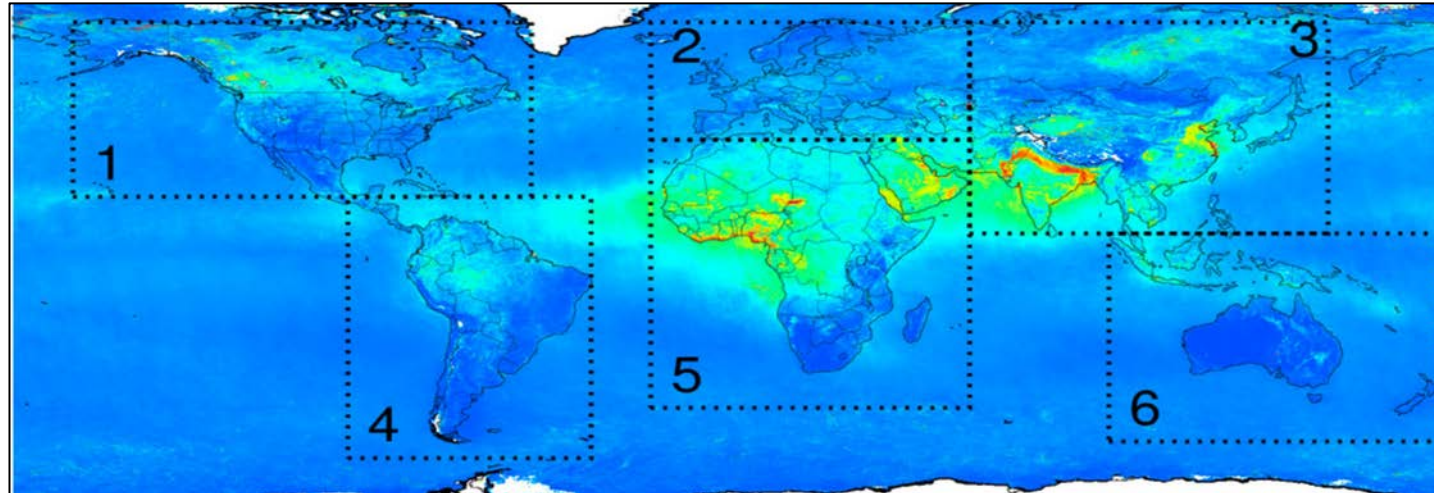
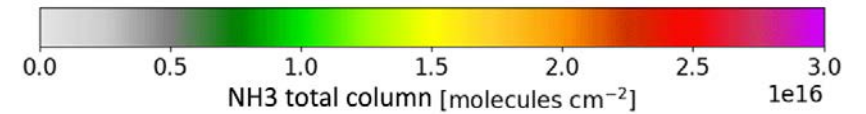
Source: De Smedt et al., 2018

# Satellite observations offer global coverage of multiple pollutants



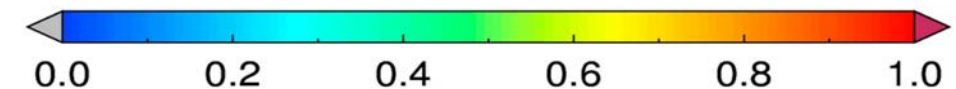
**Ammonia (NH<sub>3</sub>)**

Source: Dammers et al., 2019



**Aerosol Optical Depth (AOD)**

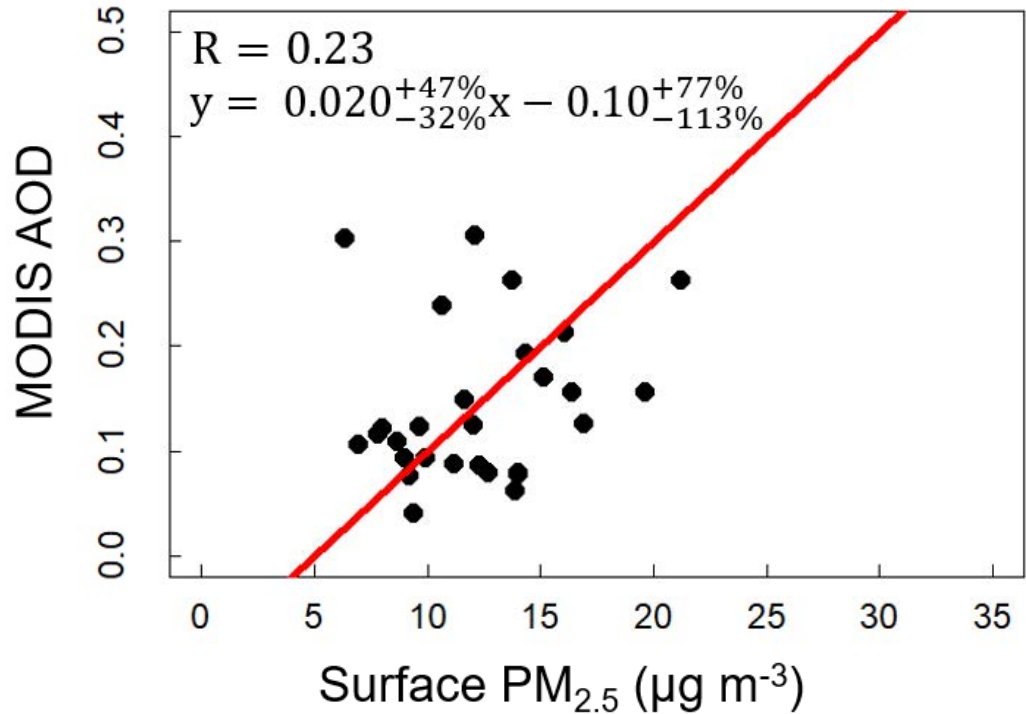
Source: Christopher and Gupta, 2020





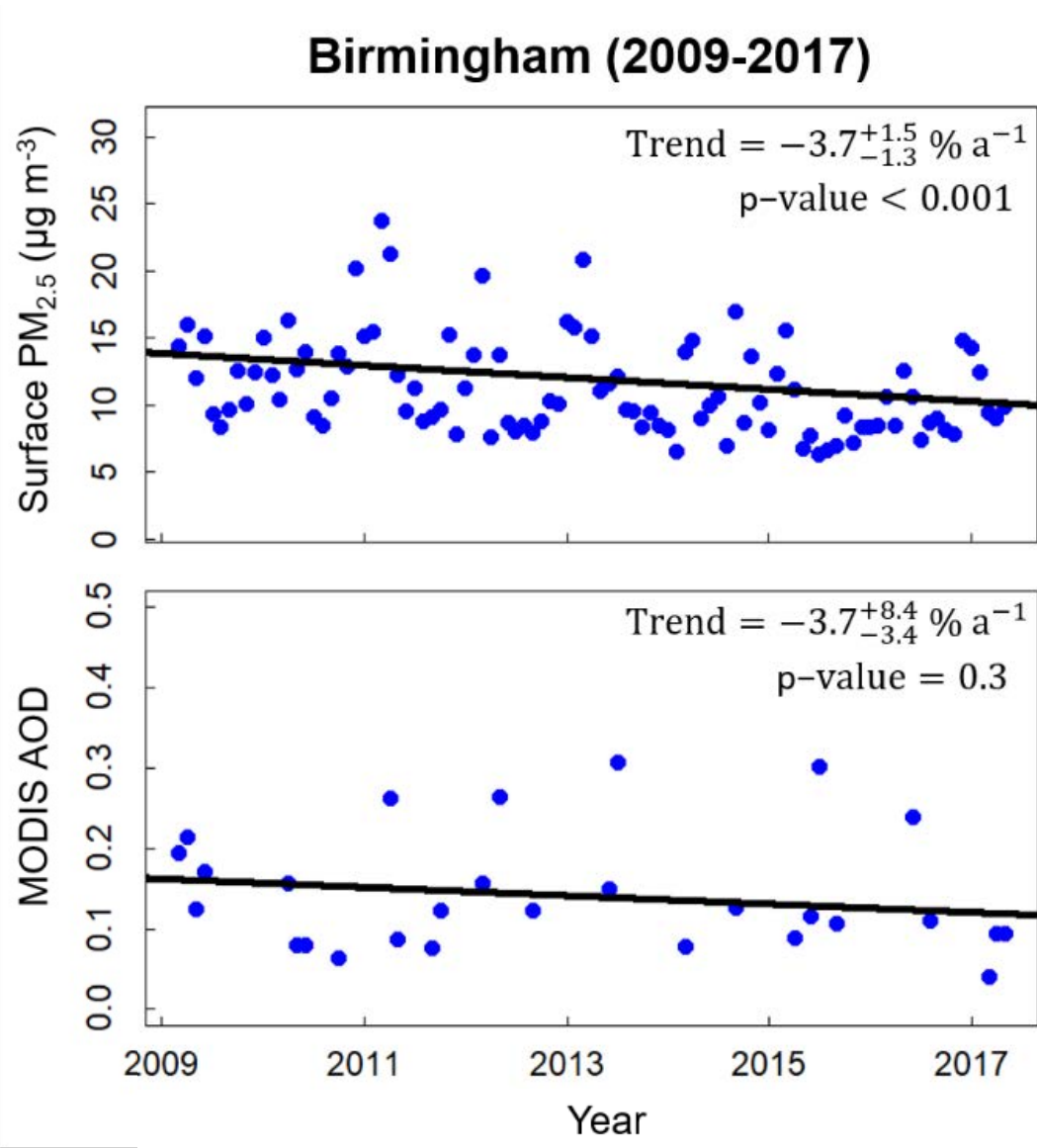
# Satellite observations of AOD reproduce trends in PM<sub>2.5</sub>

Satellite AOD versus surface PM<sub>2.5</sub>  
in **Birmingham, UK** (2009-2017)



Complicated by meteorological conditions,  
aerosol composition & vertical distribution

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



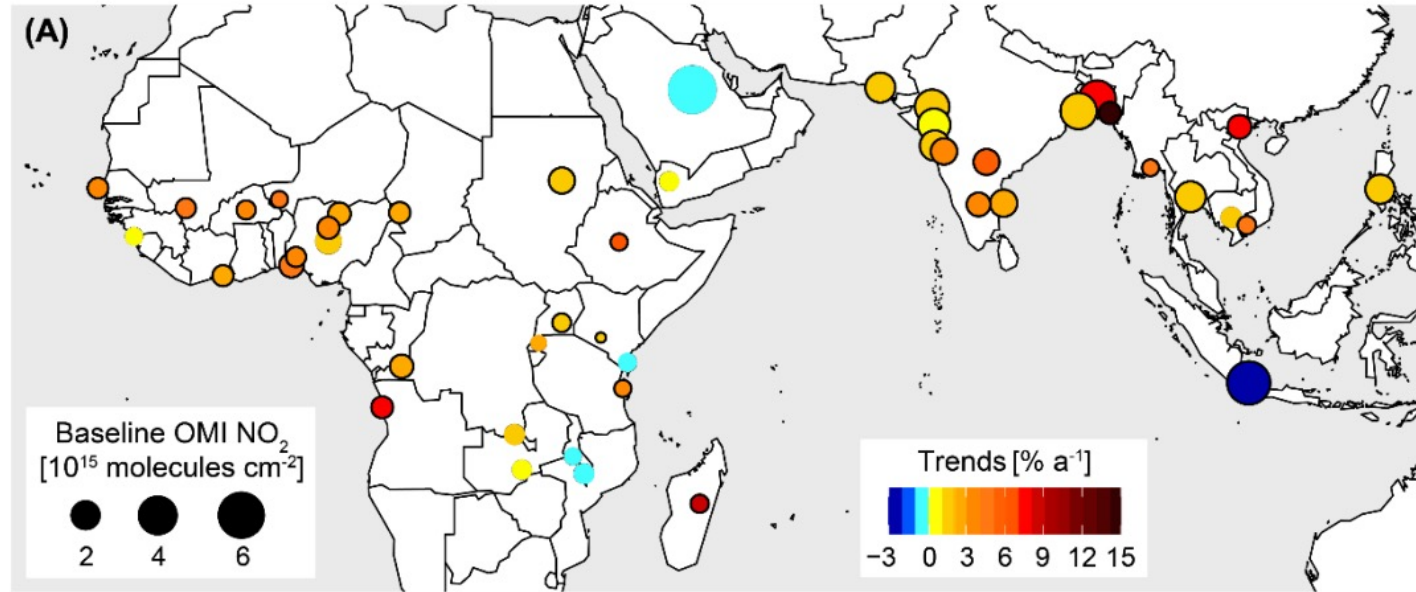
[Vohra et al., *ACP*, 2021]



# Steep annual increases in $\text{NO}_x$ and $\text{NH}_3$

$\text{NO}_2$  trends  
(proxy for  $\text{NO}_x$ )  
[2005-2018]

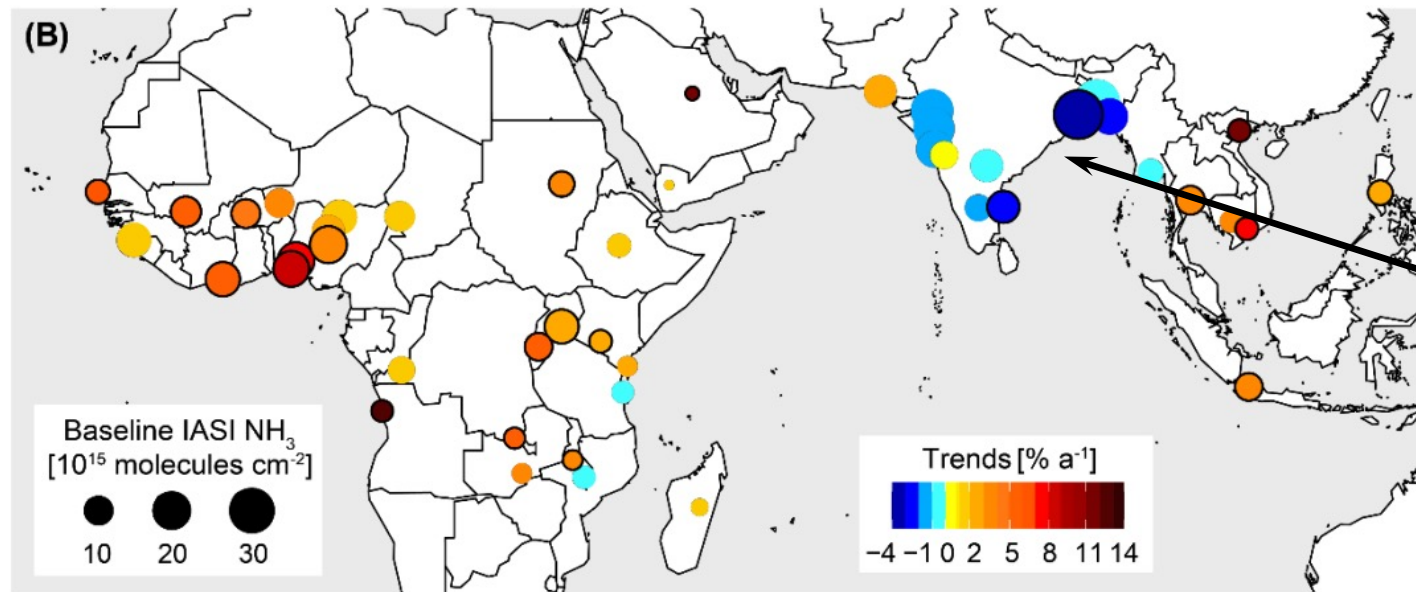
OMI: Ozone  
Monitoring  
Instrument



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

$\text{NH}_3$  trends  
(depends on acidic  
aerosol abundance)  
[2008-2018]

IASI: Infrared  
atmospheric  
sounding  
interferometer



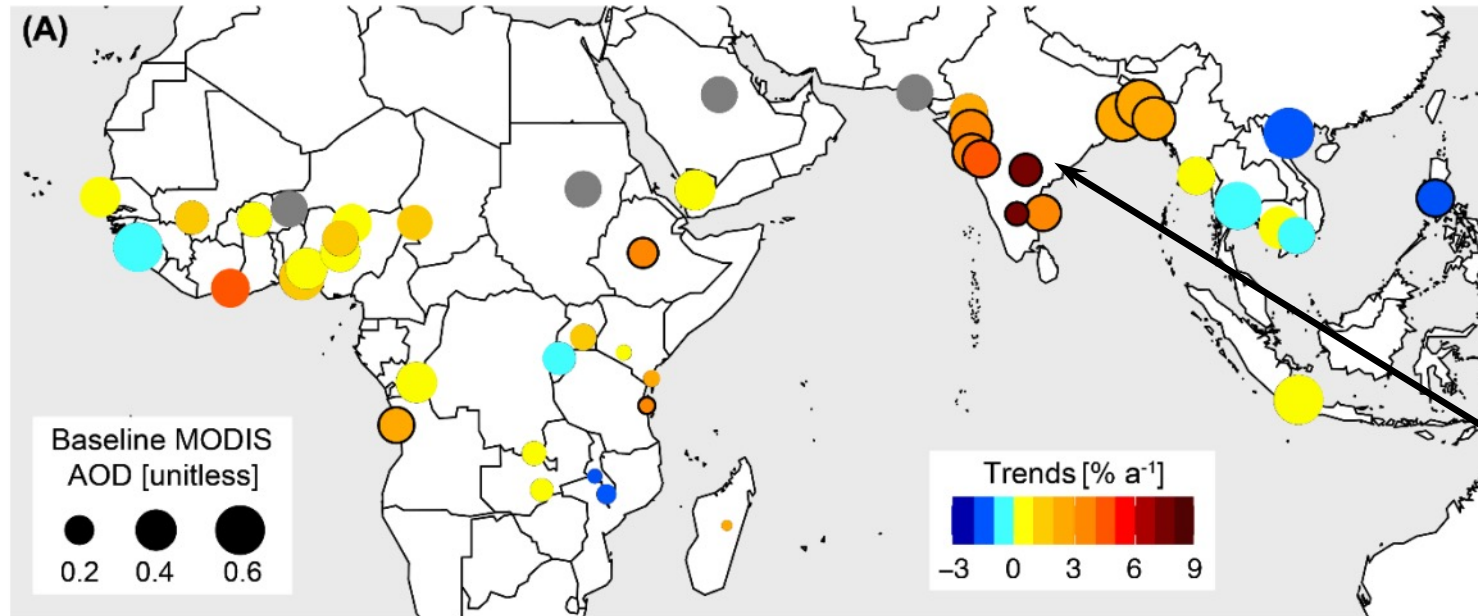
Decline over Indian  
subcontinent due to  
increase in uptake to  
acidic aerosols

$\text{NH}_3$  data from M. Van Damme, L. Clarisse, P.-F. Coheur at ULB

# Annual changes in PM<sub>2.5</sub> and ozone production regimes

**AOD trends**  
(proxy for PM<sub>2.5</sub>)  
[2005-2018]

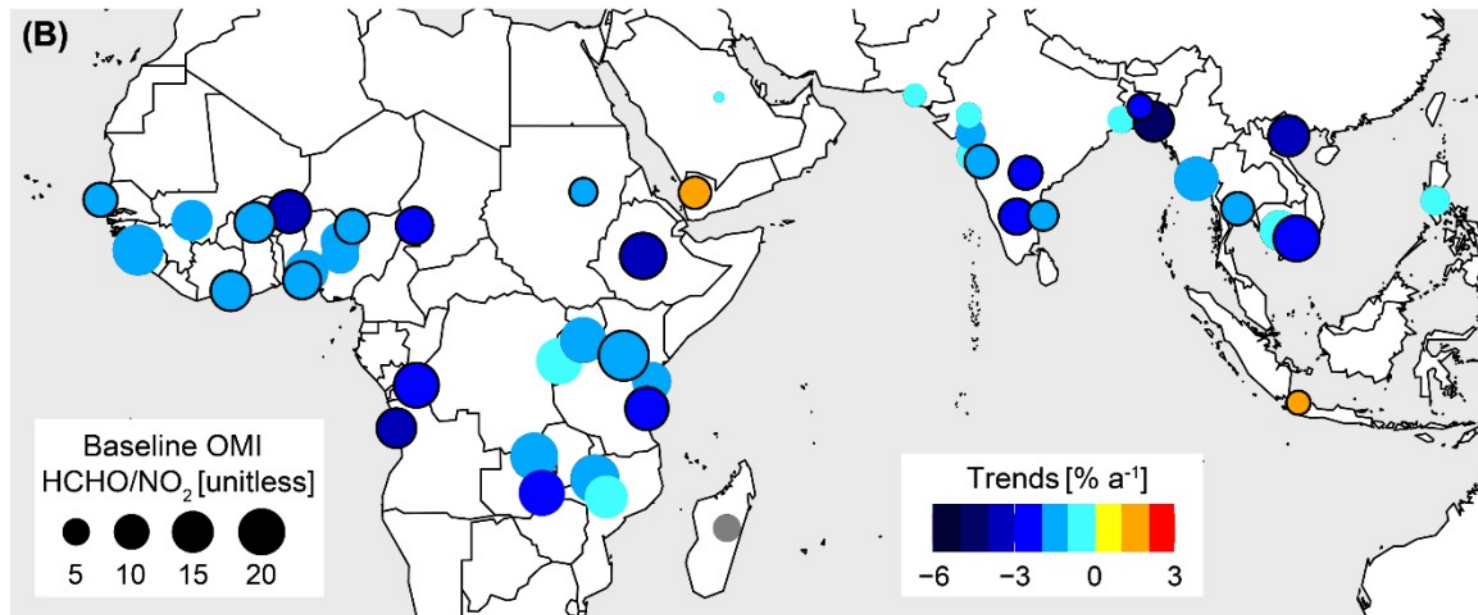
**MODIS:** Moderate  
resolution imaging  
spectroradiometer



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

Increases in PM<sub>2.5</sub>  
precursors SO<sub>2</sub>,  
NH<sub>3</sub>, NO<sub>x</sub>

**HCHO/NO<sub>2</sub> trends**  
(proxy for ozone  
production regime)  
[2005-2018]



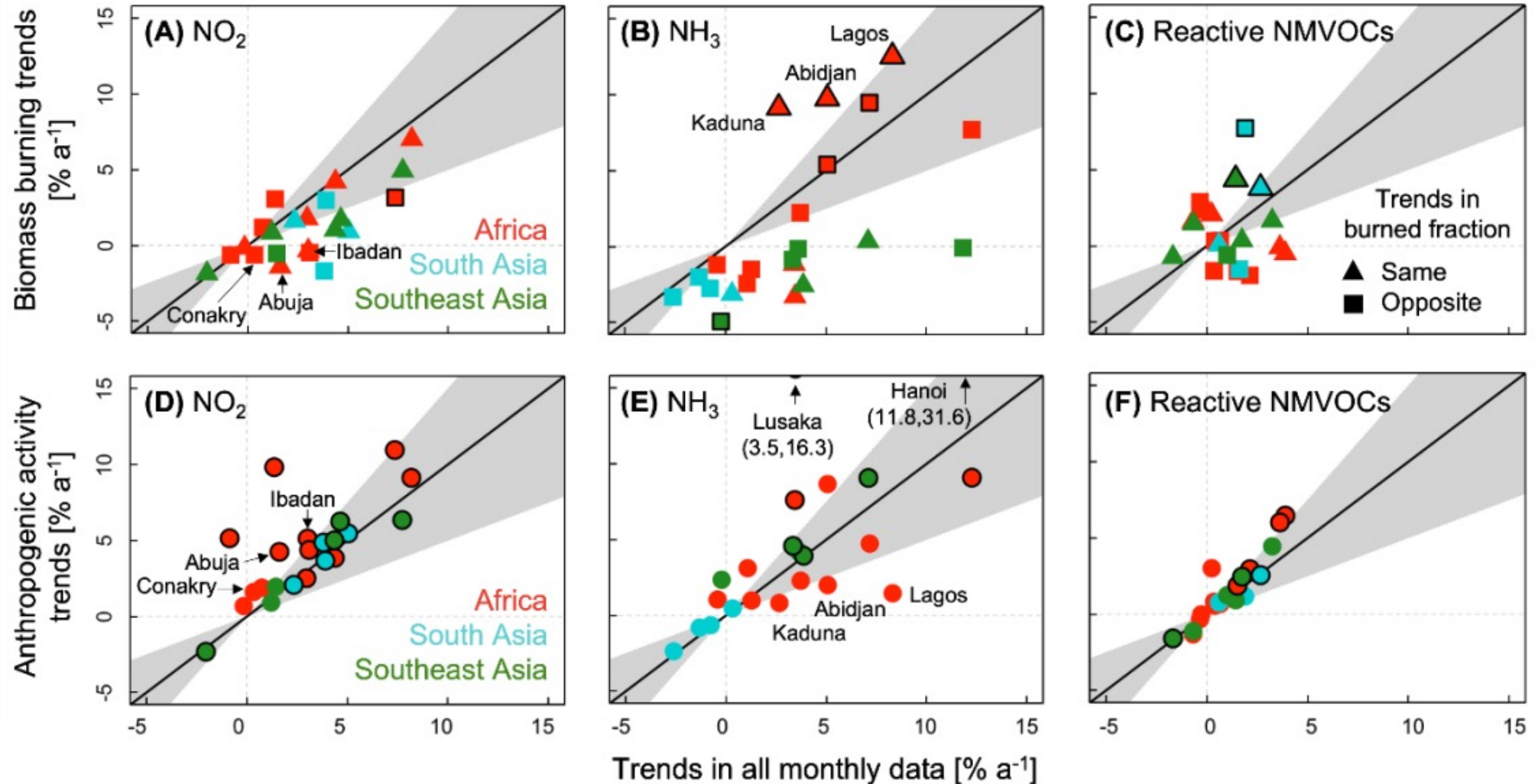
**Ratio > 5:**  
O<sub>3</sub> production  
sensitive to NO<sub>x</sub>

Transitioning to NO<sub>x</sub>  
saturated or VOC  
sensitive



# What's driving the observed trends?

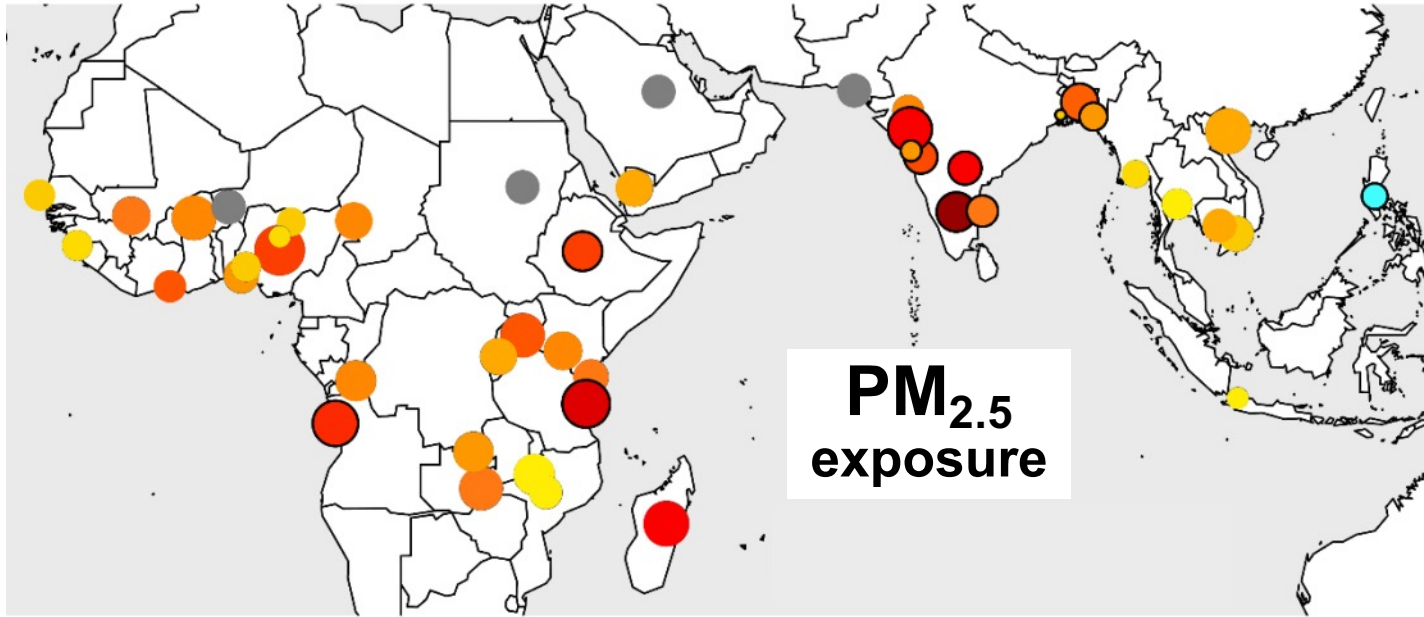
We use a statistical approach and knowledge of seasonality of emissions to assess the relative role of anthropogenic and biomass burning emission



Shift from rural fires to urban sources

Some trend dampening due to decline in agricultural activity

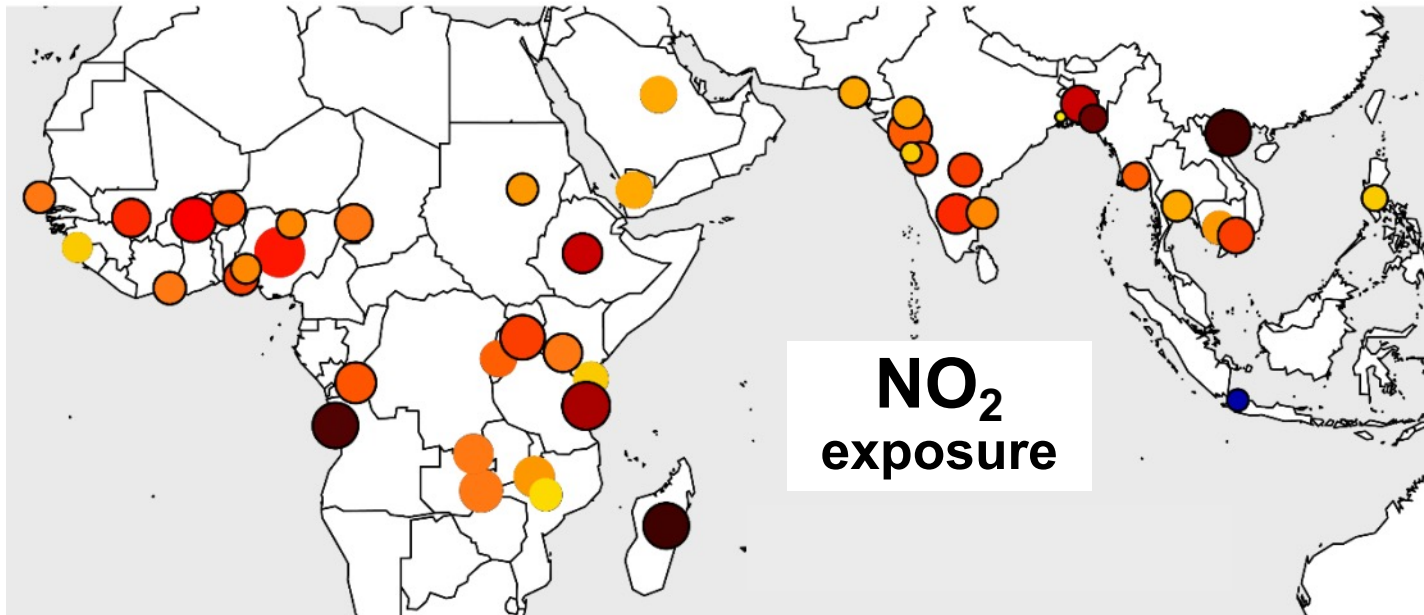
# Increase in urban population exposure to air pollution



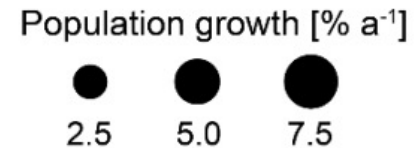
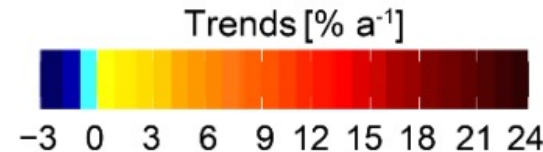
Combined effect of rapid air quality degradation, increase in population and urbanization

Up to **18 % a<sup>-1</sup>** increase in PM<sub>2.5</sub> in India

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



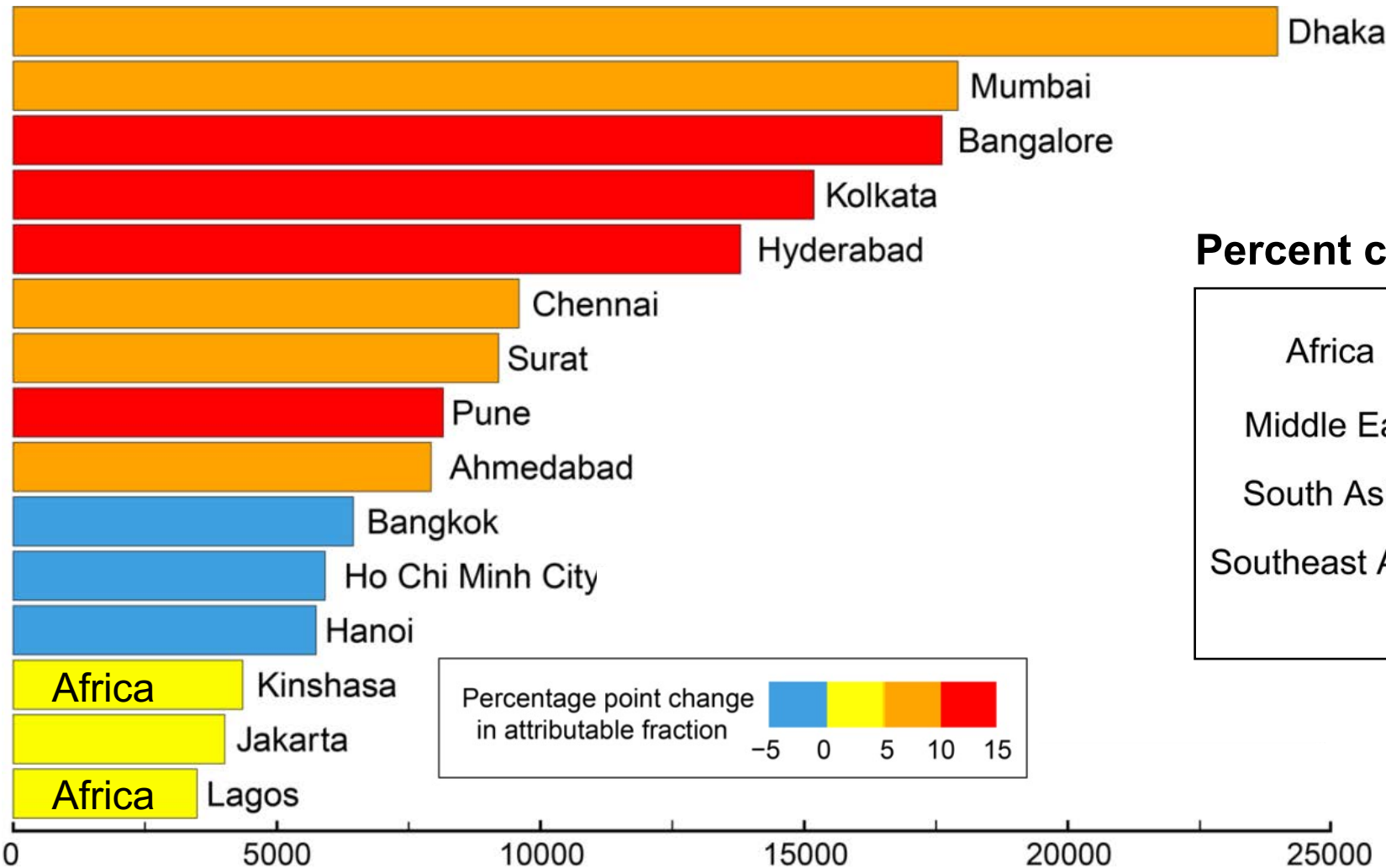
Up to **23% a<sup>-1</sup>** increase in NO<sub>2</sub> in many cities





# Premature mortality attributable to rise in PM<sub>2.5</sub> exposure

## Ranking of cities with greatest health burden

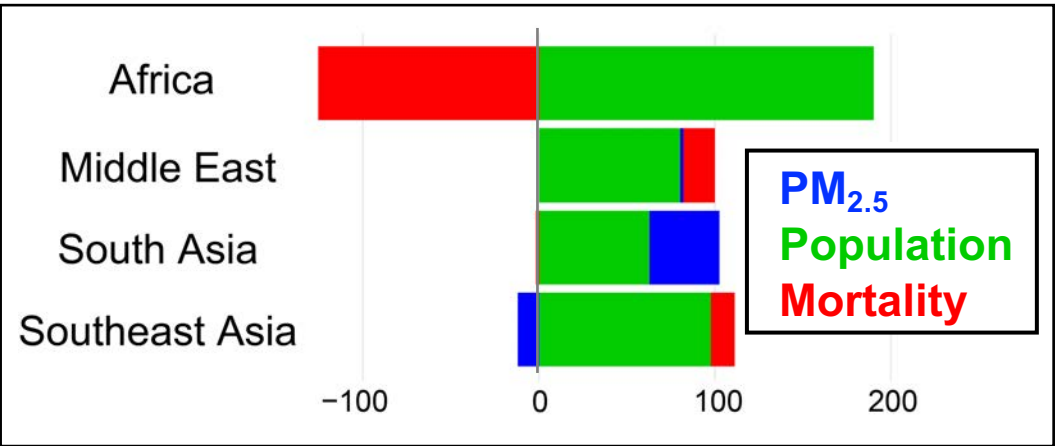


290,000 in 2005

62% ▲

470,000 in 2018

## Percent contribution of individual factors



**Total: 179,550**

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

Increase in premature deaths from 2005 to 2018

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<sub>x</sub> 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>