

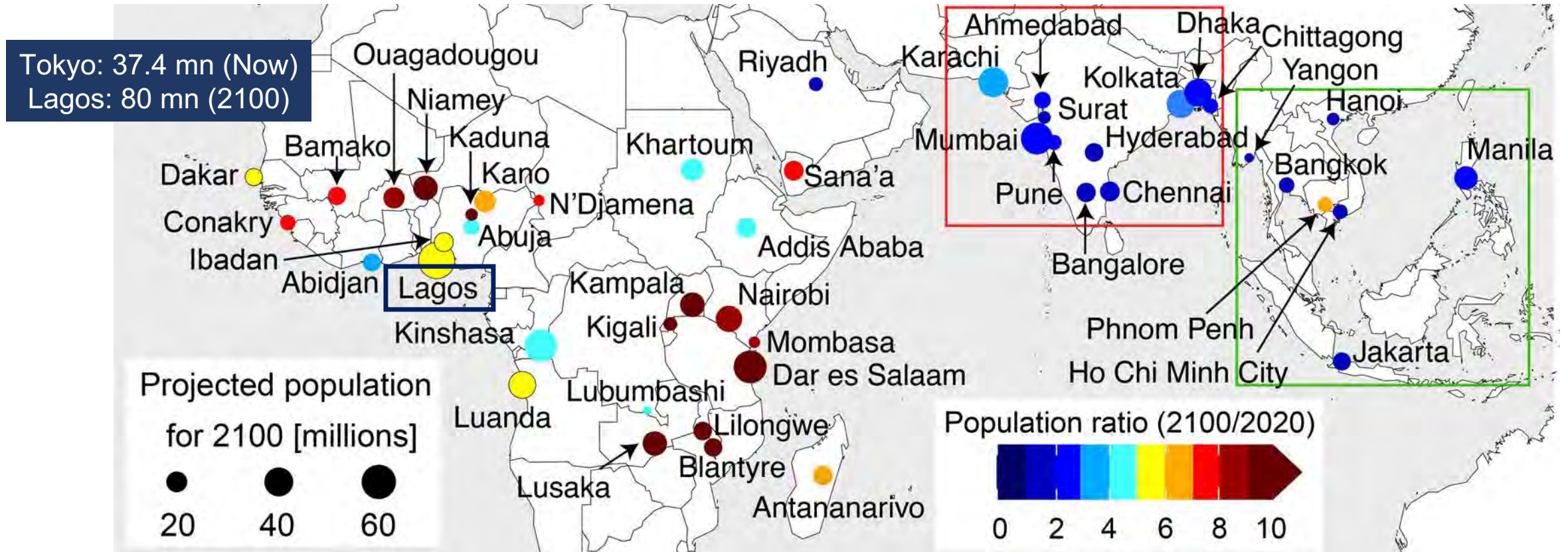


Severe Health Burden in Tropical Future Megacities from the Rapid Rise in Anthropogenic Air Pollution and Population

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Tropical cities are experiencing unprecedented growth

46 cities in tropical Asia, Africa and the Middle East will be megacities by 2100

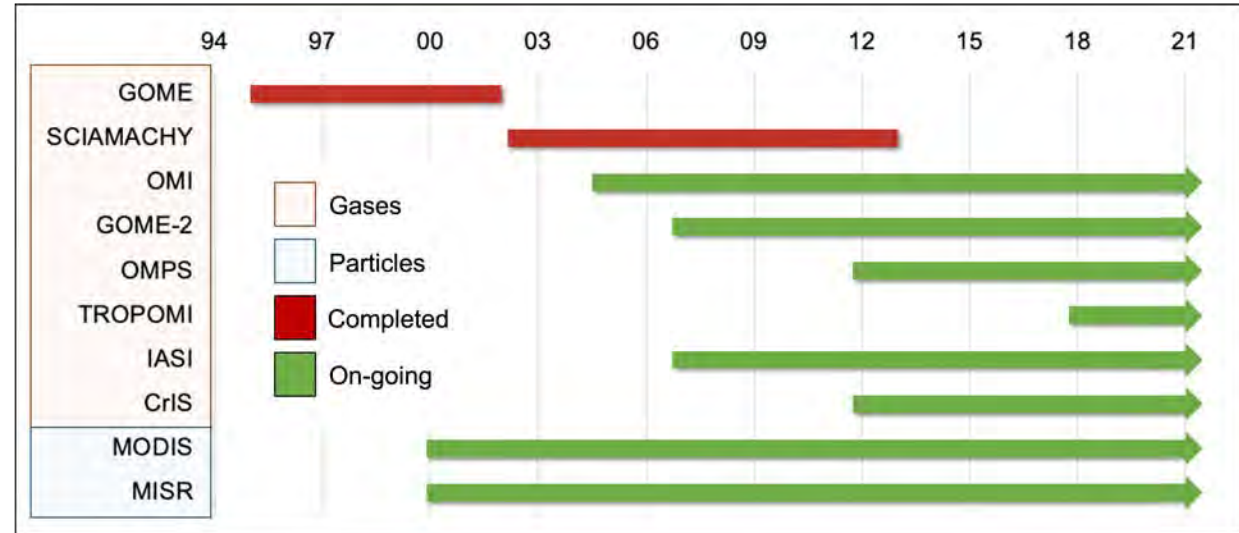
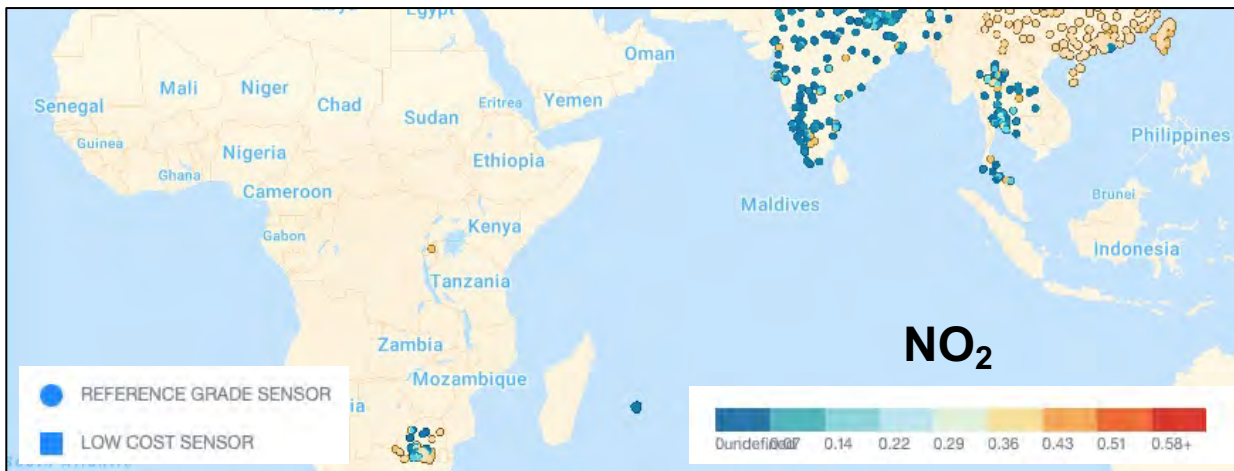
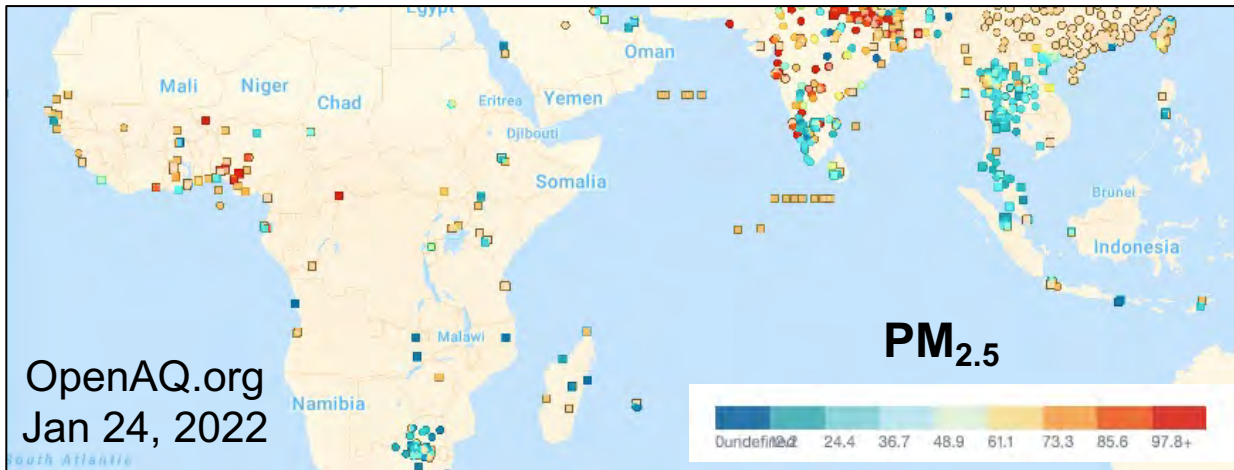


Forecast annual growth rates for 2020-2100: 3-31% in Africa, 0.8-3% in **South Asia** and 0.5-7% in **Southeast Asia** [Hoornweg & Pope, 2017]

Tropical cities are the next frontier in air pollution

Currently, limited surface monitoring of air pollutants across the tropics

Long and consistent record of atmospheric composition from space-based instruments



OMI for **NO₂** and **HCHO** (proxy for NMVOCs)

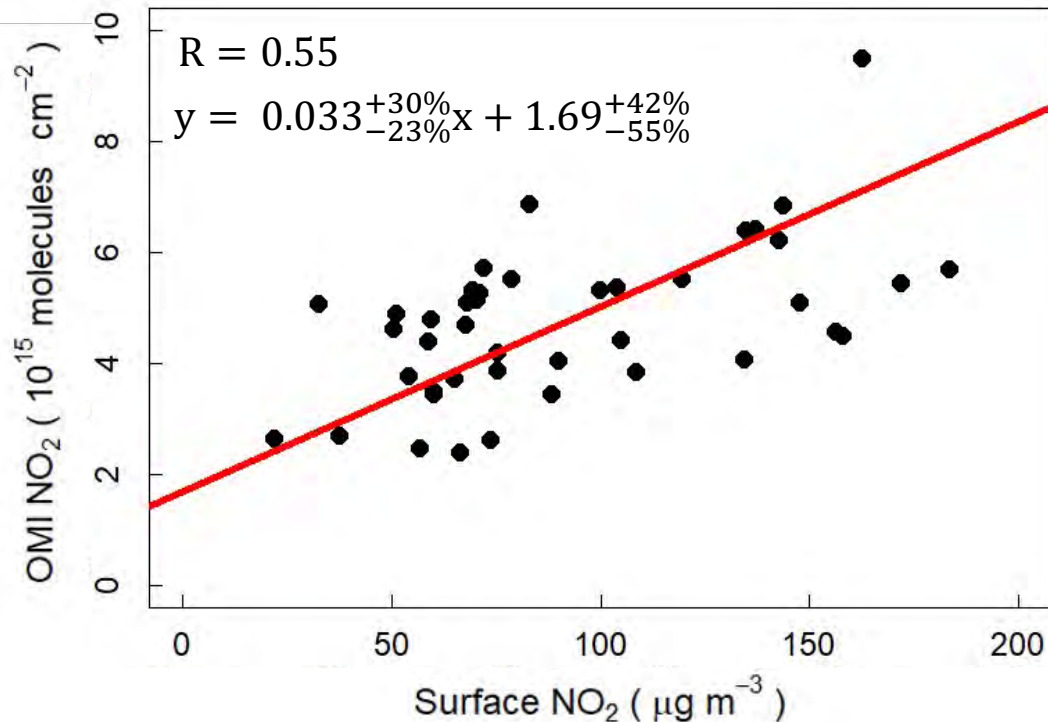
IASI for **NH₃**

MODIS for **AOD** (proxy for PM_{2.5})

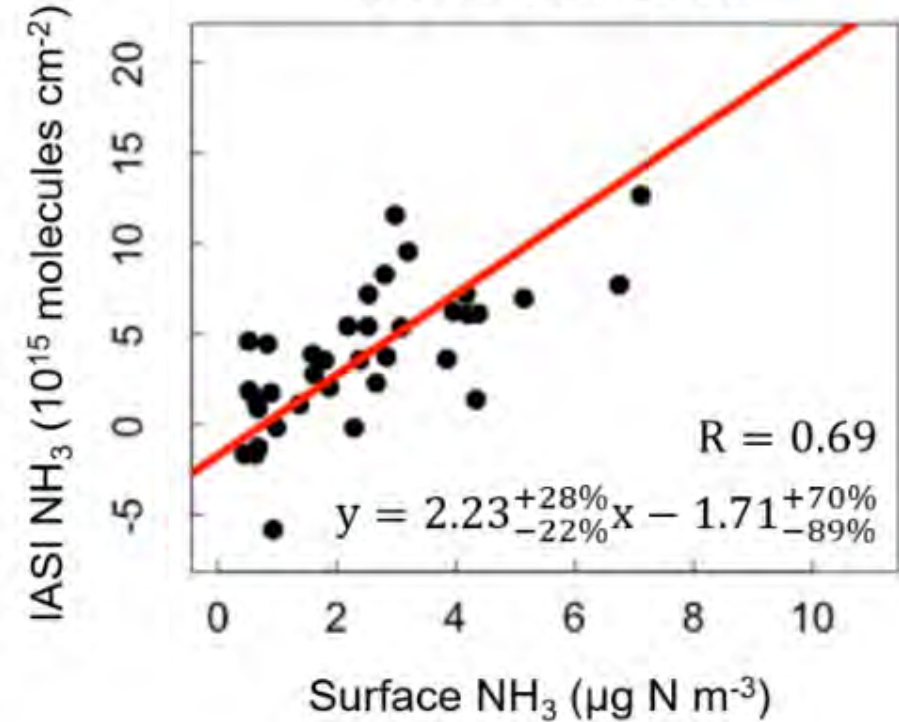
< 1 monitor per million people [Martin et al., 2019]

Assessing the skill of satellite observations at reproducing variability in surface air quality

Satellite versus surface NO_2 in **Delhi, India** (2011-2018)



Satellite versus surface NH_3 at the background site **Harwell, UK** (2011-2015)

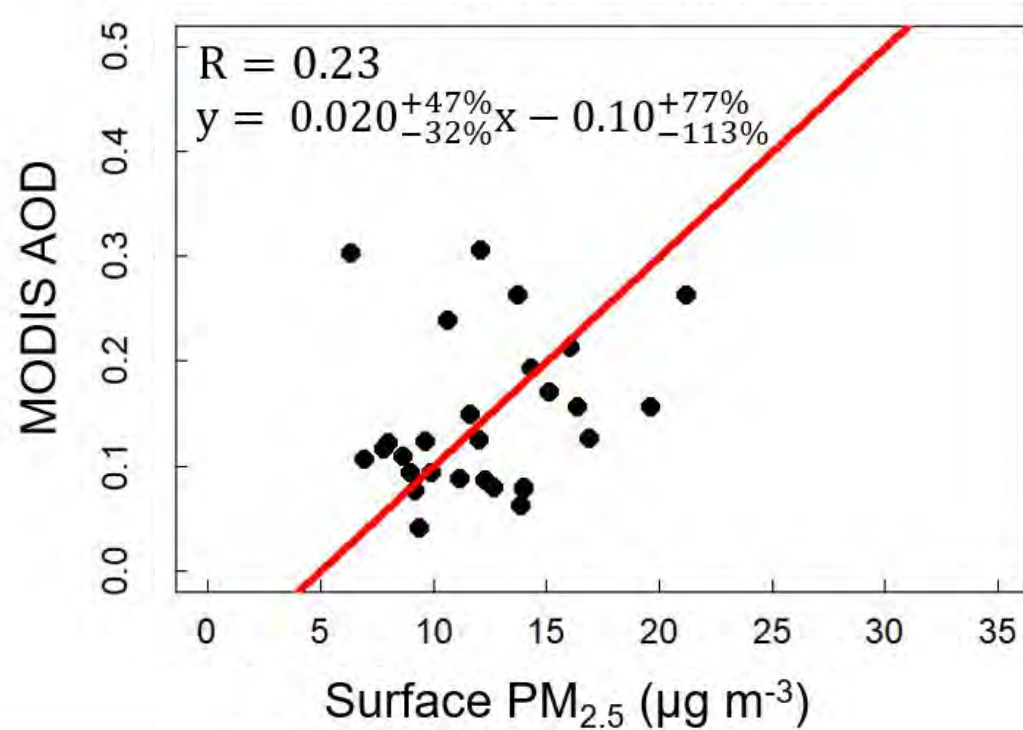


Temporal consistency between satellite and surface measurements of NO_2 and NH_3

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

Satellite observations of AOD reproduce long-term trends in PM_{2.5}

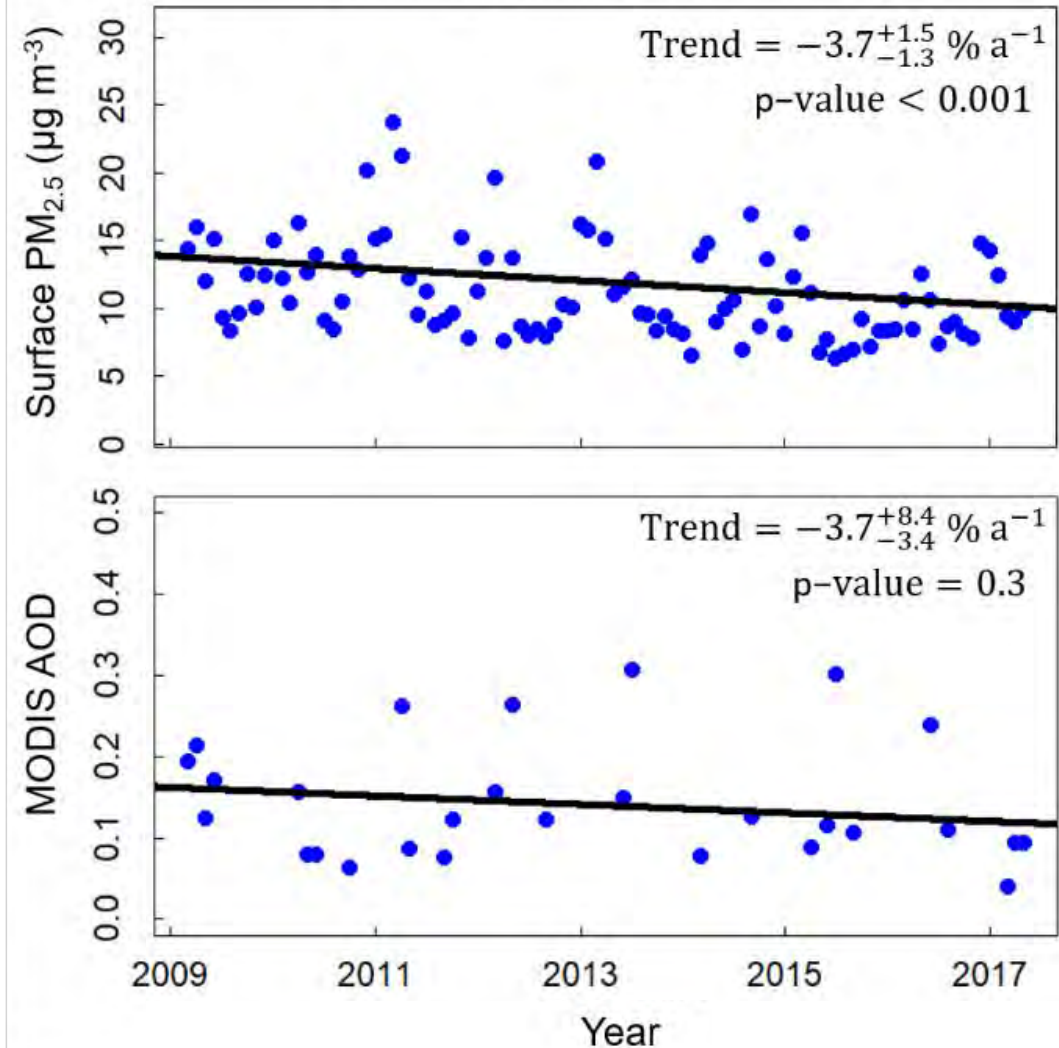
Satellite AOD versus surface PM_{2.5} in Birmingham, UK (2009-2017)



Complicated by meteorological conditions,
aerosol composition & vertical distribution

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

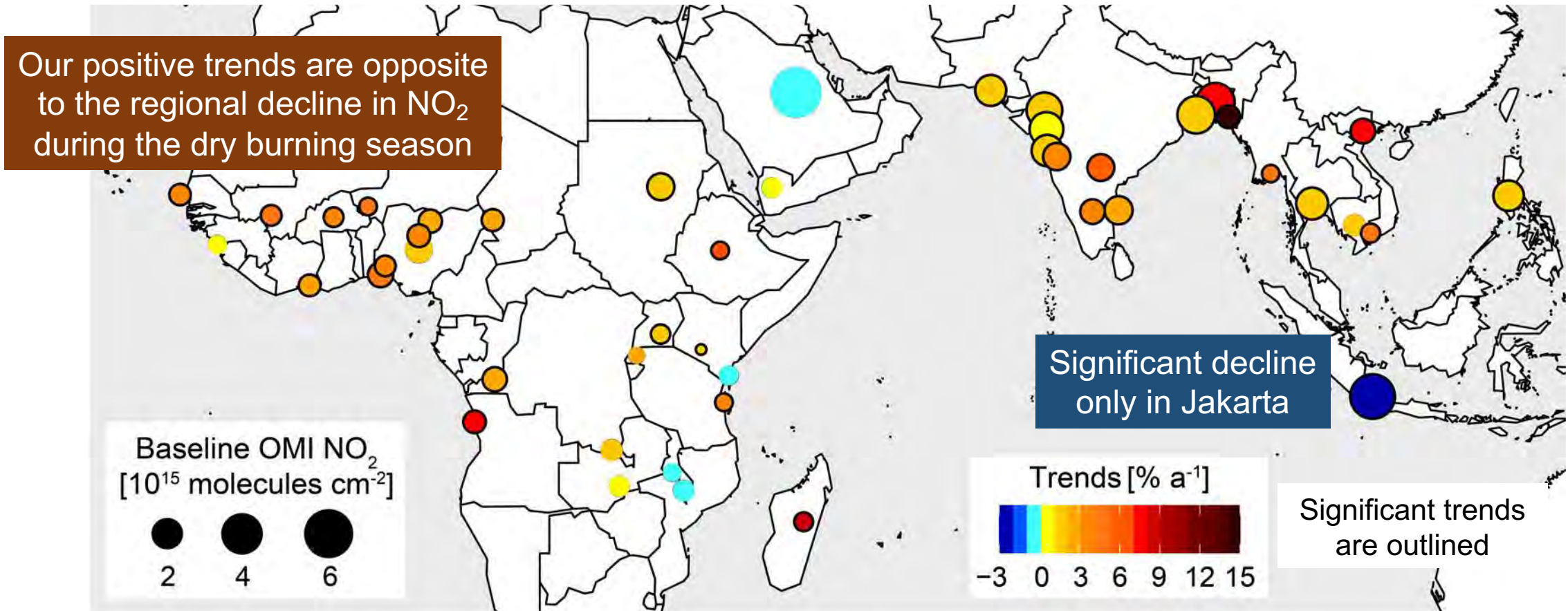
Birmingham (2009-2017)



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

Trends in NO₂ in tropical future megacities in 2005-2018

NO₂ increases in 41 cities by 0.1-14.1 % a⁻¹



Steep increases in NO₂ with implications for ozone formation and aerosol nitrate

[Vohra et al., *in review*]

Trends in ozone production regimes in 2005-2018

Satellite observations of HCHO/NO_2 are used as proxy for ozone production regimes

HCHO/NO_2

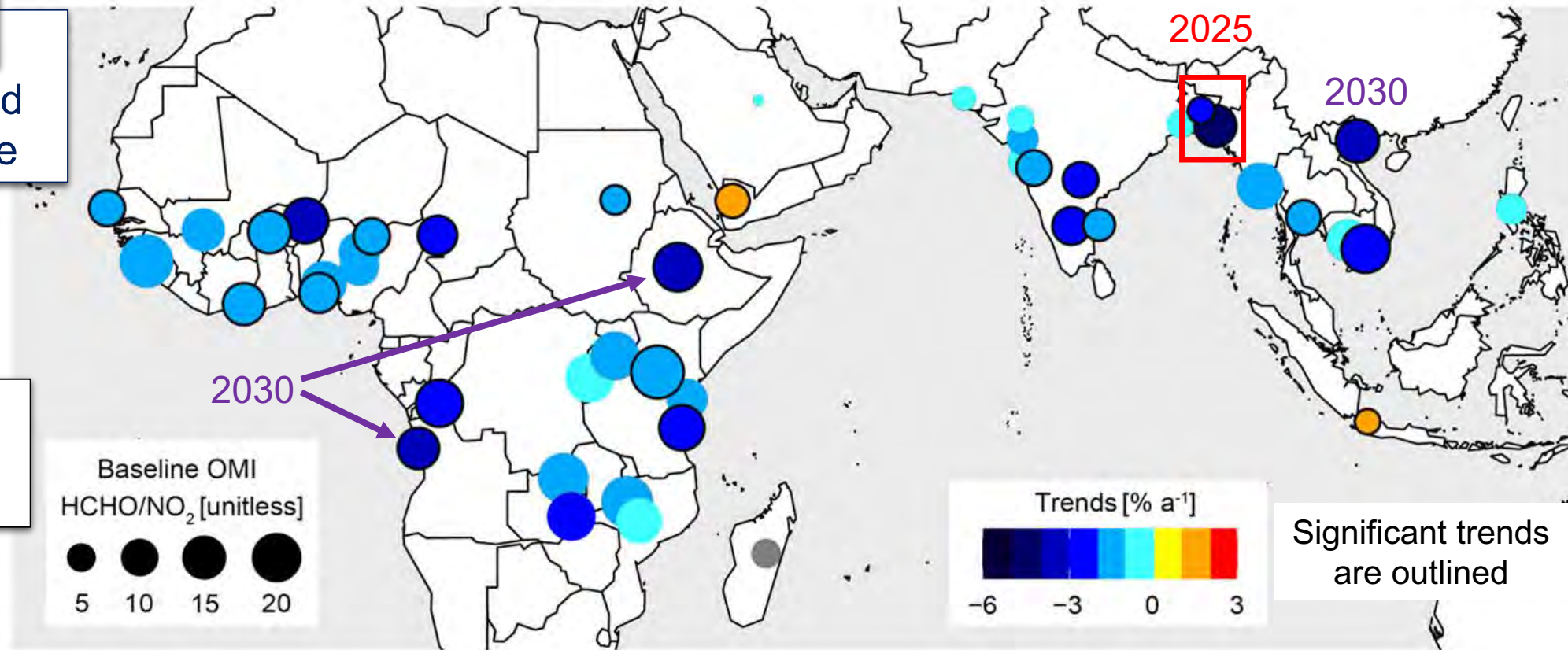
$< 1 \Rightarrow \text{NO}_x\text{-saturated}$
 $> 1 \Rightarrow \text{NO}_x\text{-sensitive}$

[Martin et al., 2004]

Limitation

Depends on local
oxidation regime

[Jin et al., 2017;
Souri et al., 2020]

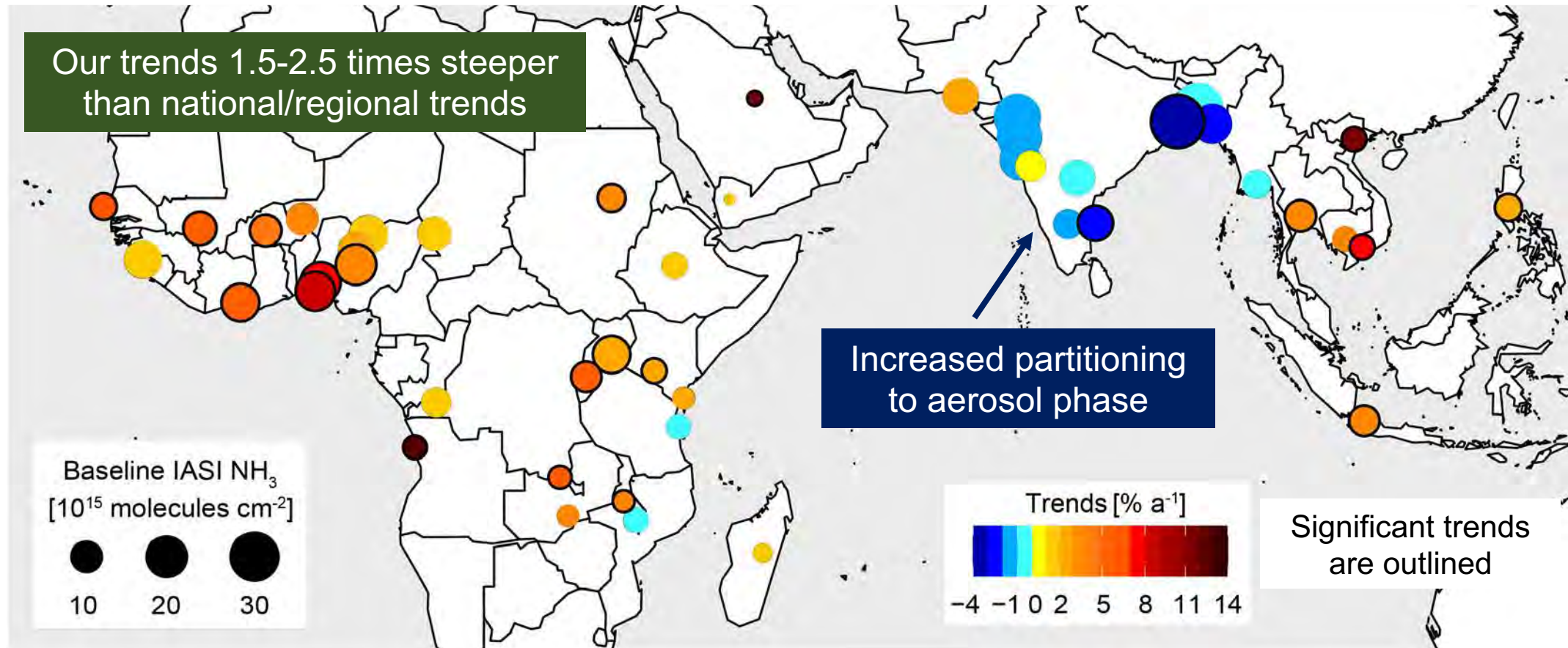


All cities except Jakarta and Sana'a are in NO_x -sensitive regime;
Gradual transition to NO_x -saturated regime may occur as early as 2025

[Vohra et al., *in review*]

Trends in NH_3 in tropical future megacities in 2008-2018

NH_3 increases in cities in all regions except the Indian subcontinent

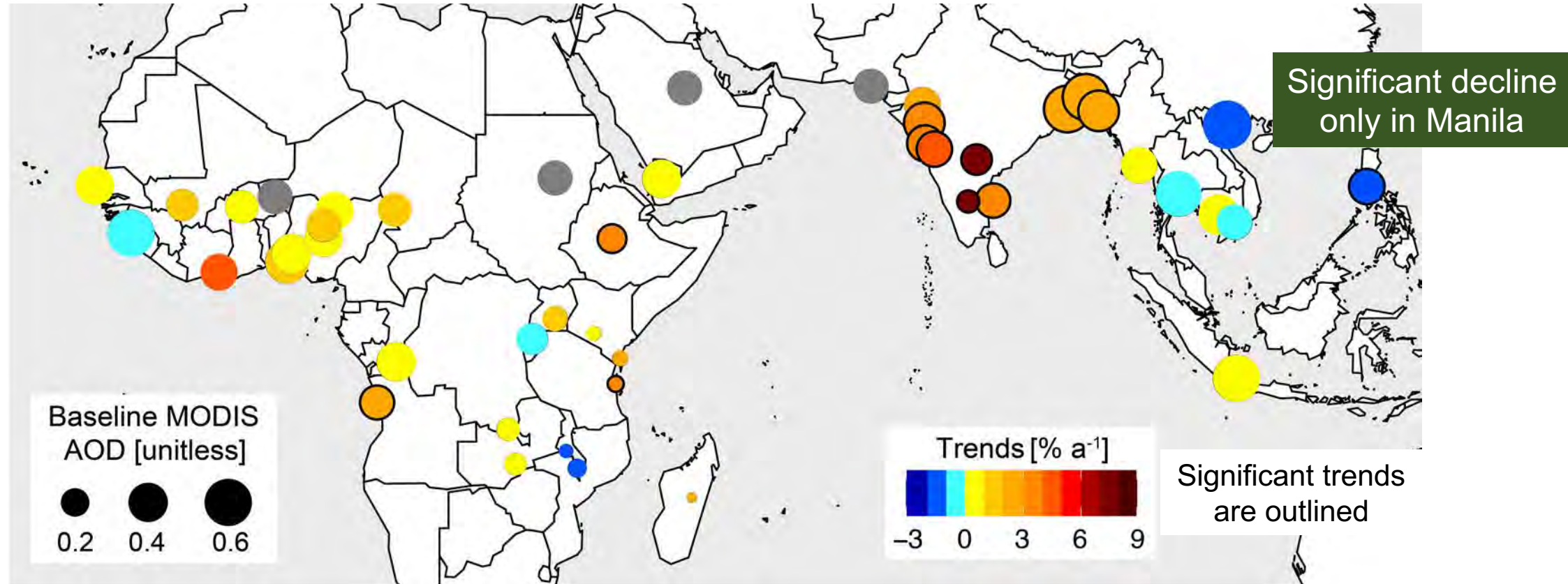


Steep increasing trends in cities in Africa and Southeast Asia may reflect increasing urban sources of NH_3

[Vohra et al., *in review*]

Trends in PM_{2.5} in tropical future megacities in 2005-2018

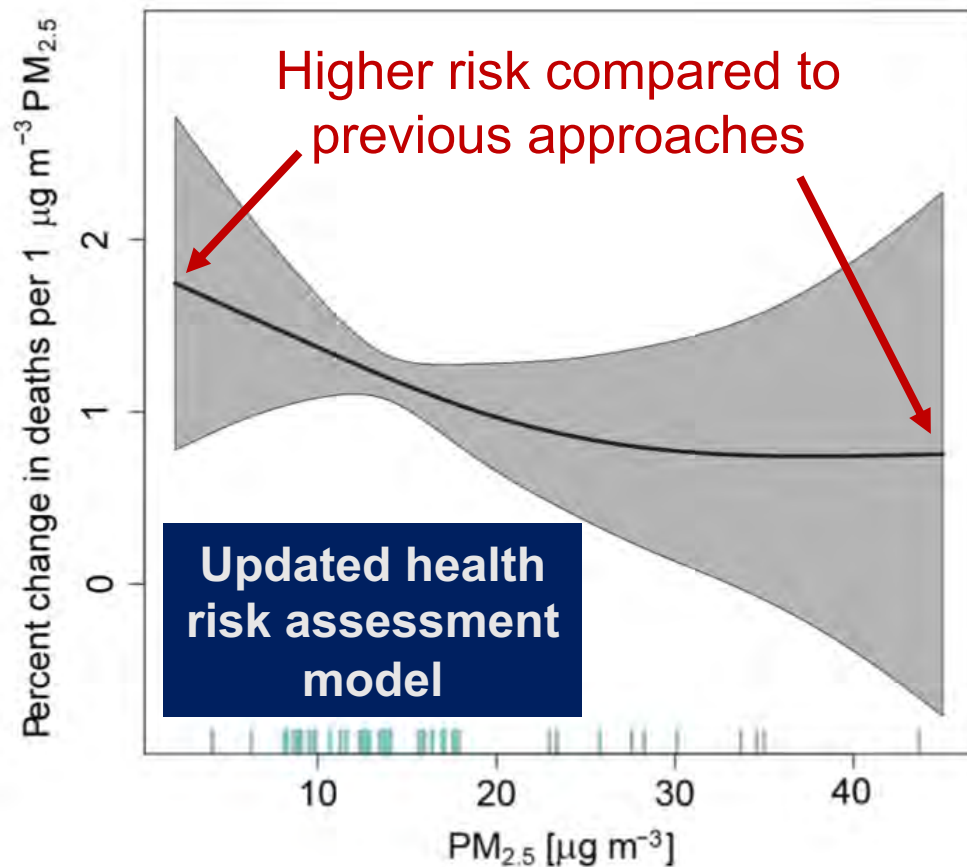
Large and significant increases of 3-8 % a⁻¹ in PM_{2.5} over Indian subcontinent



The large increase in South Asian cities is driven by an increase in PM_{2.5} precursor emissions and not desert dust

Determine premature mortality from exposure to PM_{2.5}

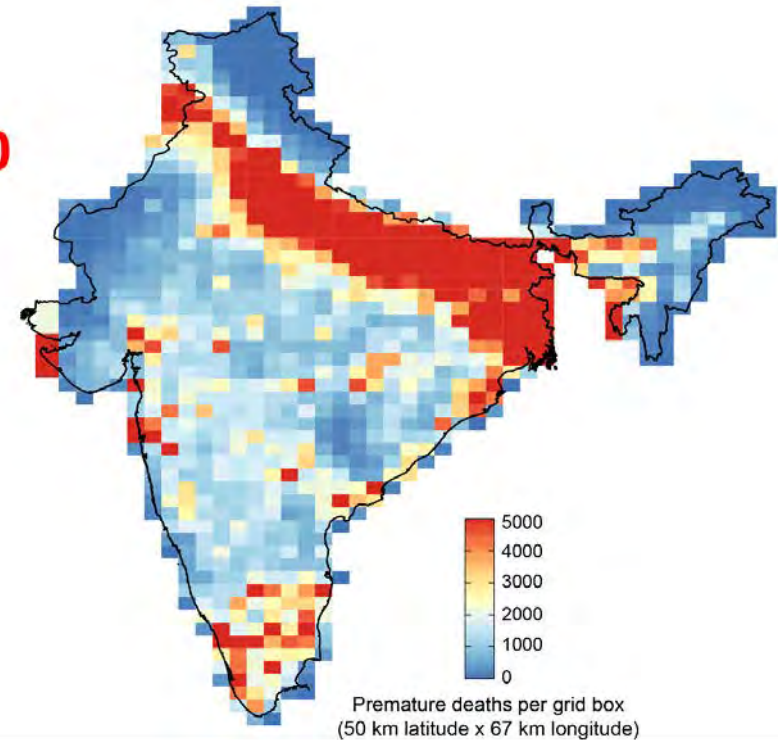
More cohorts, wider age and PM_{2.5} range and more health endpoints than GBD function



[Vodonos et al., 2018]

Higher premature mortality estimates than previous studies

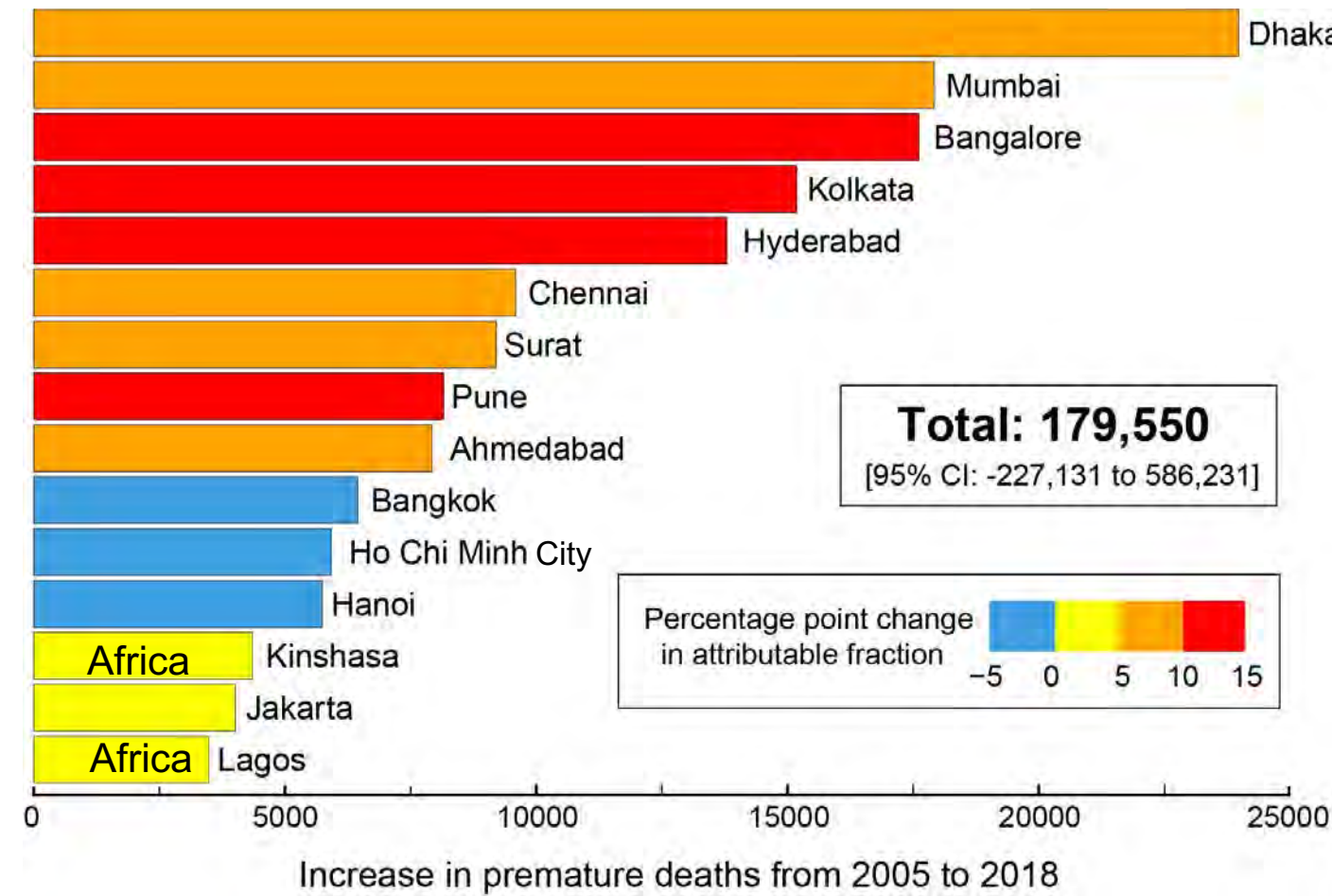
India
2,500,000



Premature deaths linked to PM_{2.5} from fossil fuel combustion in 2012

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

Severe health burden in tropical future megacities

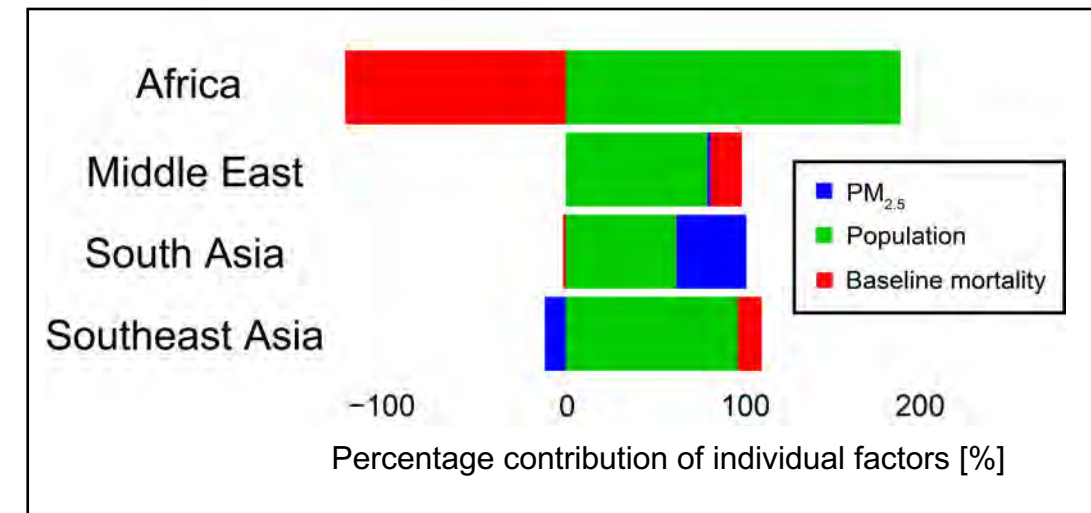


Premature mortality from long-term PM_{2.5} exposure

290,000 in 2005

62% ▲

470,000 in 2018



Largest increases in premature mortality in cities in Asia

Effects of PM_{2.5} on health in African cities countered by decline in baseline mortality [Vohra et al., *in review*]

Conclusion

- Most pollutants in almost all tropical cities increase at rates 2-3 times faster than or opposite in direction to reported national and regional trends
- Only Jakarta shows evidence of air quality improvements due to policy measures, and those improvements have had a limited effect, leading to decline in NO_2 but not in NH_3 or $\text{PM}_{2.5}$
- Ozone formation is on track to transition from strongly NO_x -sensitive to the more challenging to regulate VOC-sensitive regime
- We estimate an increase in premature mortality of **180,000** linked to the rapid rise in anthropogenic air pollution in these fastest-growing tropical cities

Reference

K. Vohra, E. A. Marais, W. J. Bloss, J. Schwartz, L. J. Mickley, M. Van Damme, L. Clarisse, P.-F. Coheur, Rapid rise in premature mortality due to anthropogenic air pollution in fast-growing tropical cities from 2005 to 2018, in review, *Science Advances*.

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