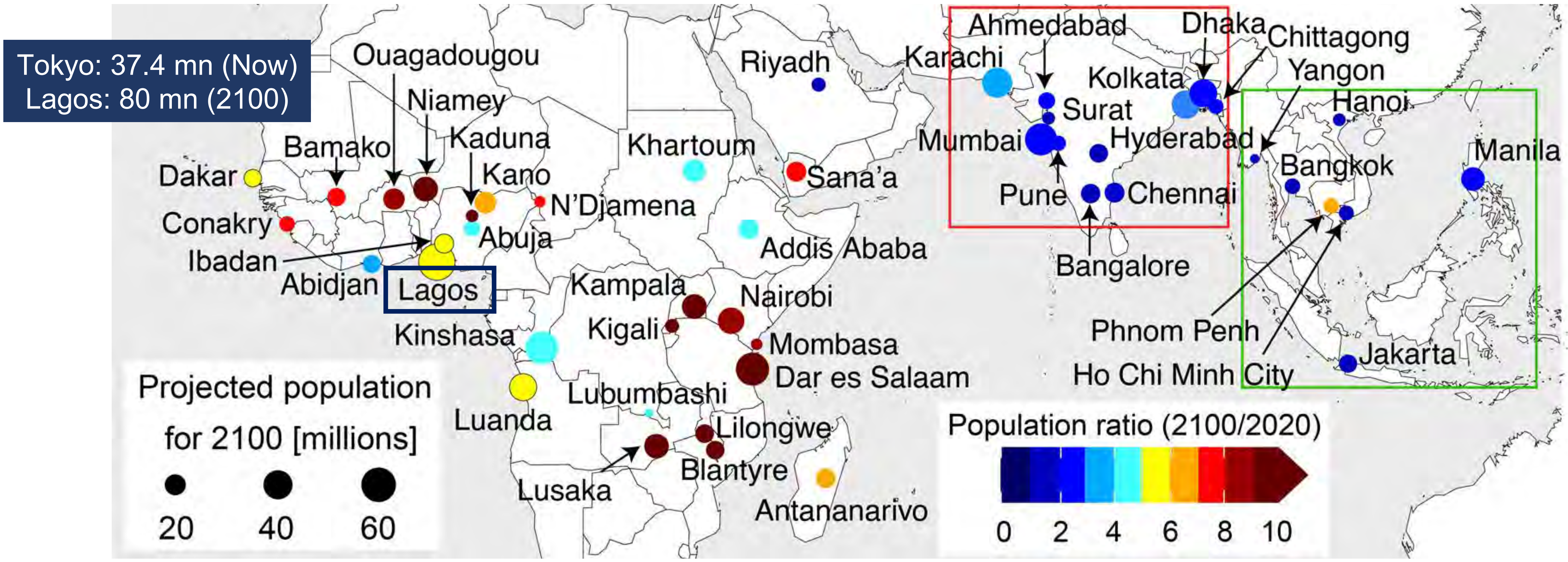
Joint International Atmospheric Chemistry Conference 2022
17th Science Conference IGAC 15th Quadrennial Symposium iCACGP

Rapid rise in premature mortality in fast-growing tropical cities due to anthropogenic air pollution

Karn Vohra (k.vohra@ucl.ac.uk), E. A. Marais, W. J. Bloss, J. Schwartz, L. J. Mickley, M. Van Damme, L. Clarisse, P.-F. Coheur

Tropical cities are experiencing unprecedented growth

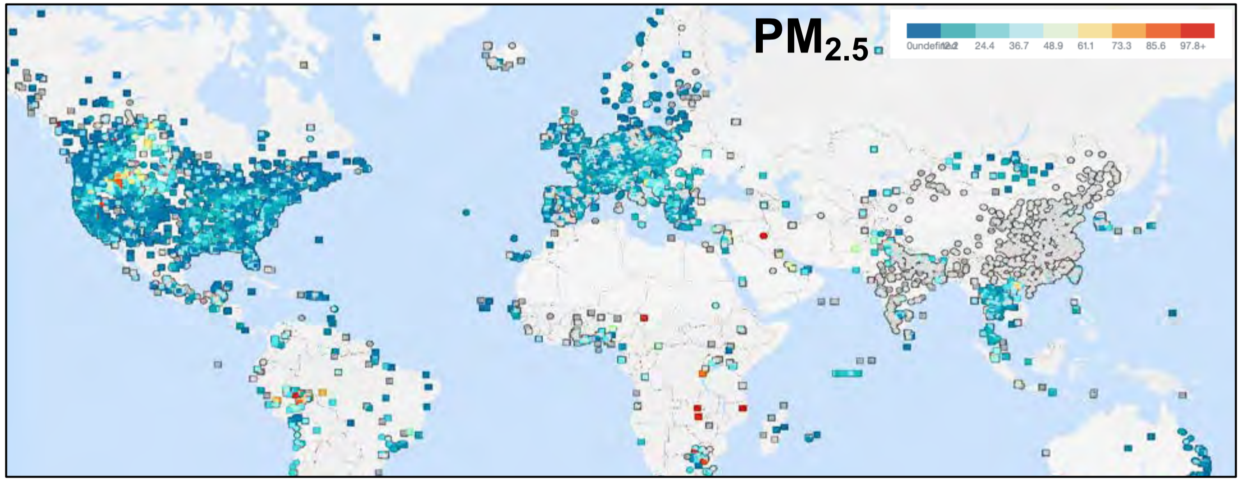
46 cities in tropical Asia, Africa and the Middle East will be megacities by 2100

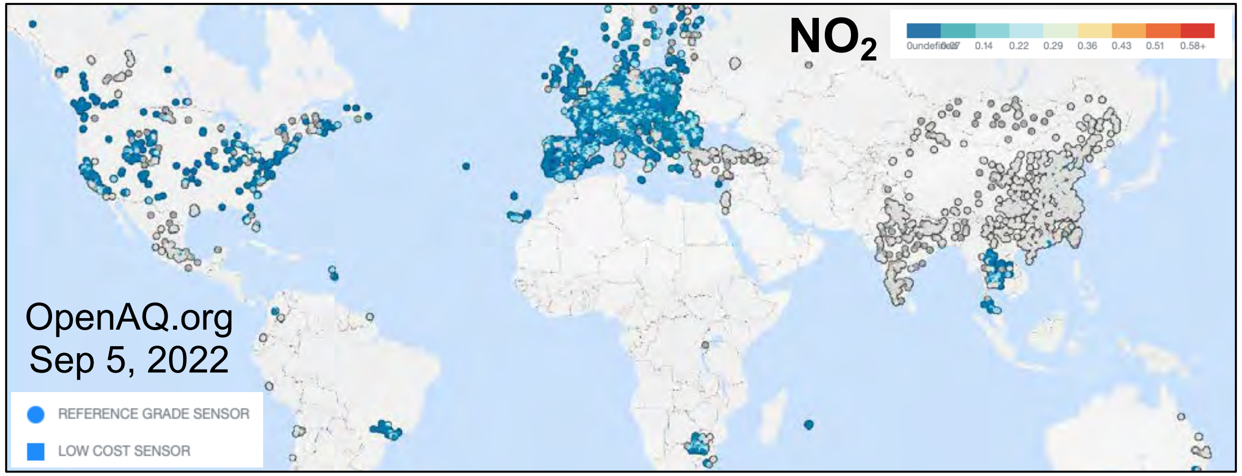


Forecast annual growth rates for 2020-2100: 3-31% in Africa, 0.8-3% in South Asia and 0.5-7% in Southeast Asia [Hoornweg & Pope, 2017]

Tropical cities are the next frontier in air pollution

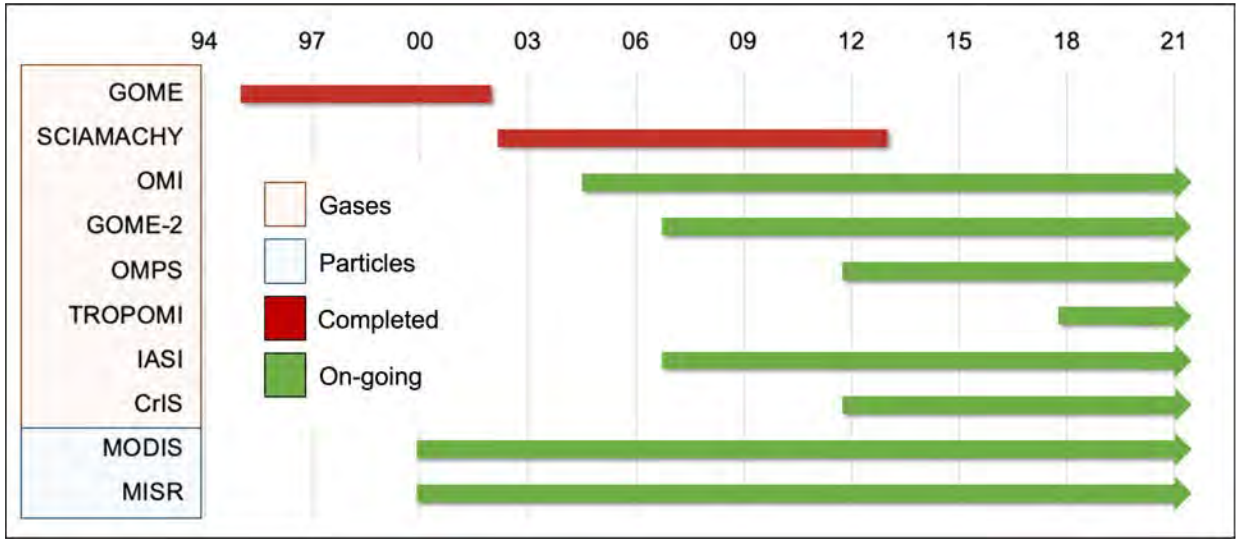
Currently, limited surface monitoring of air pollutants across the tropics





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

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



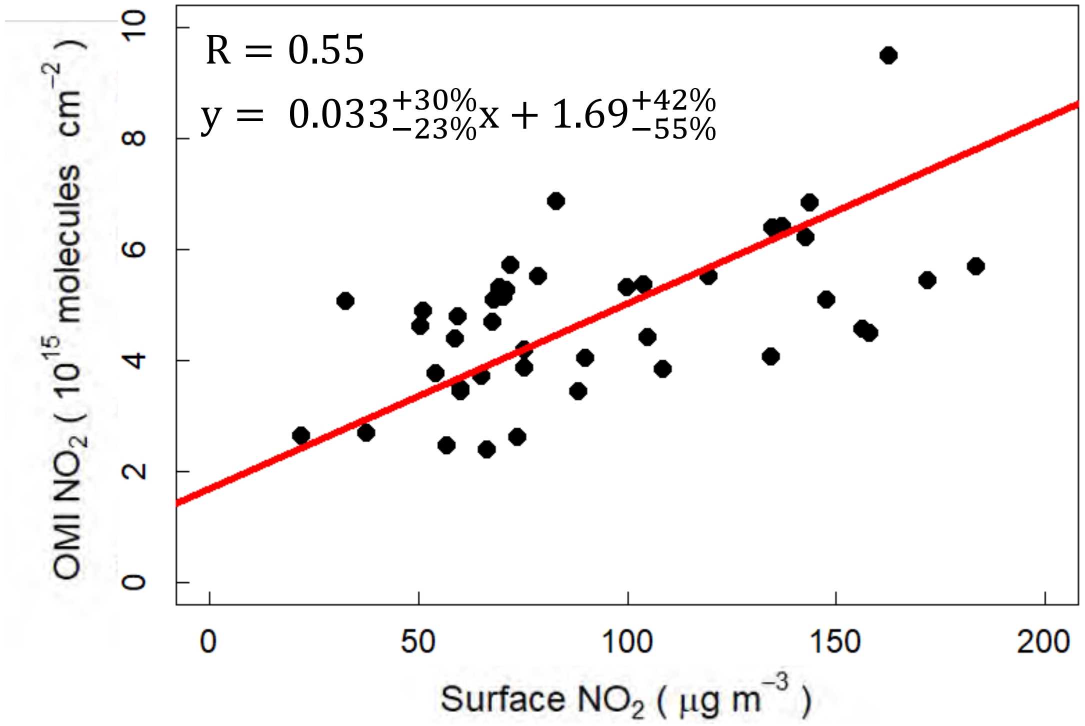
OMI for **NO_2** and **HCHO** (proxy for NMVOCs)

IASI for **NH_3**

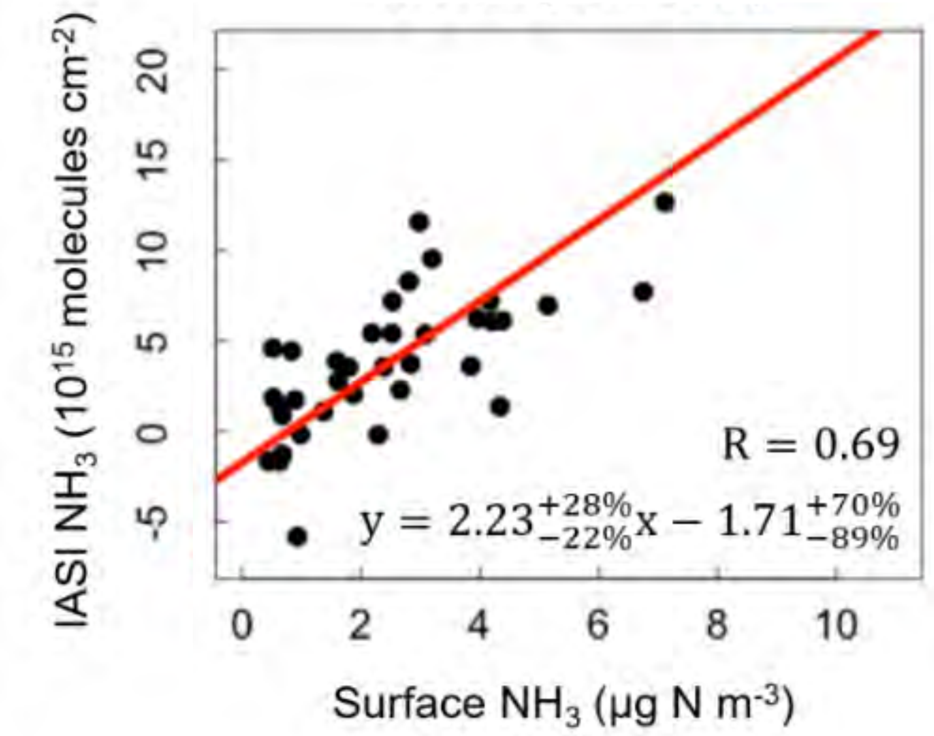
MODIS for **AOD** (proxy for $PM_{2.5}$)

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)

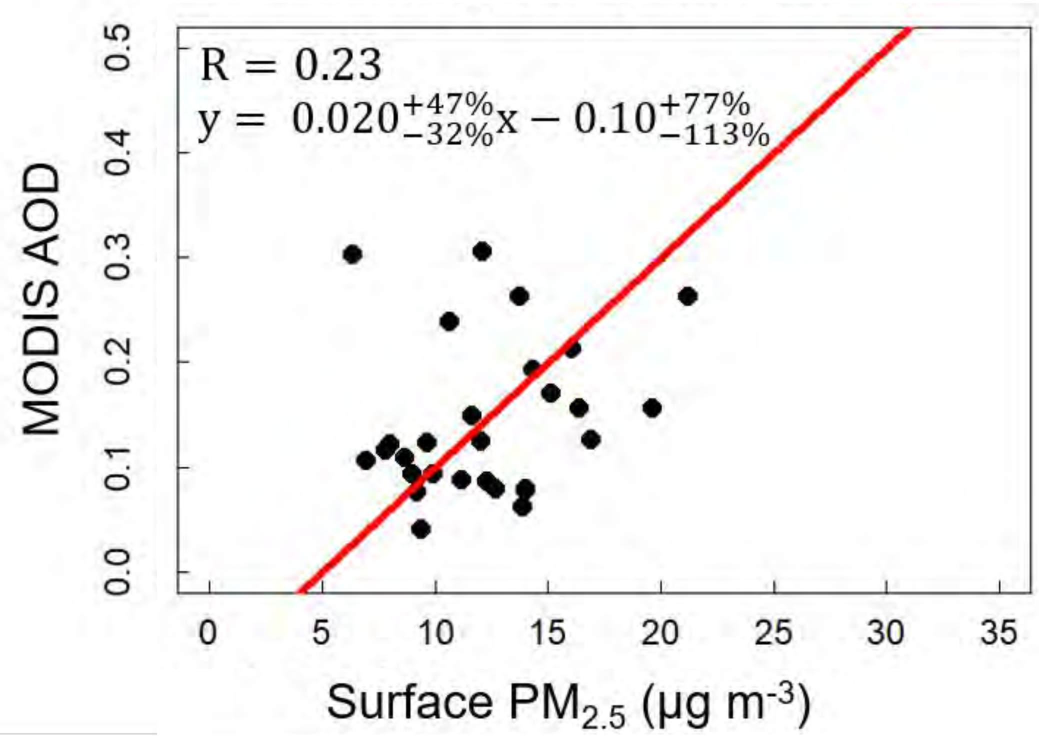


Temporal consistency between satellite and surface measurements of NO_2 and NH_3

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

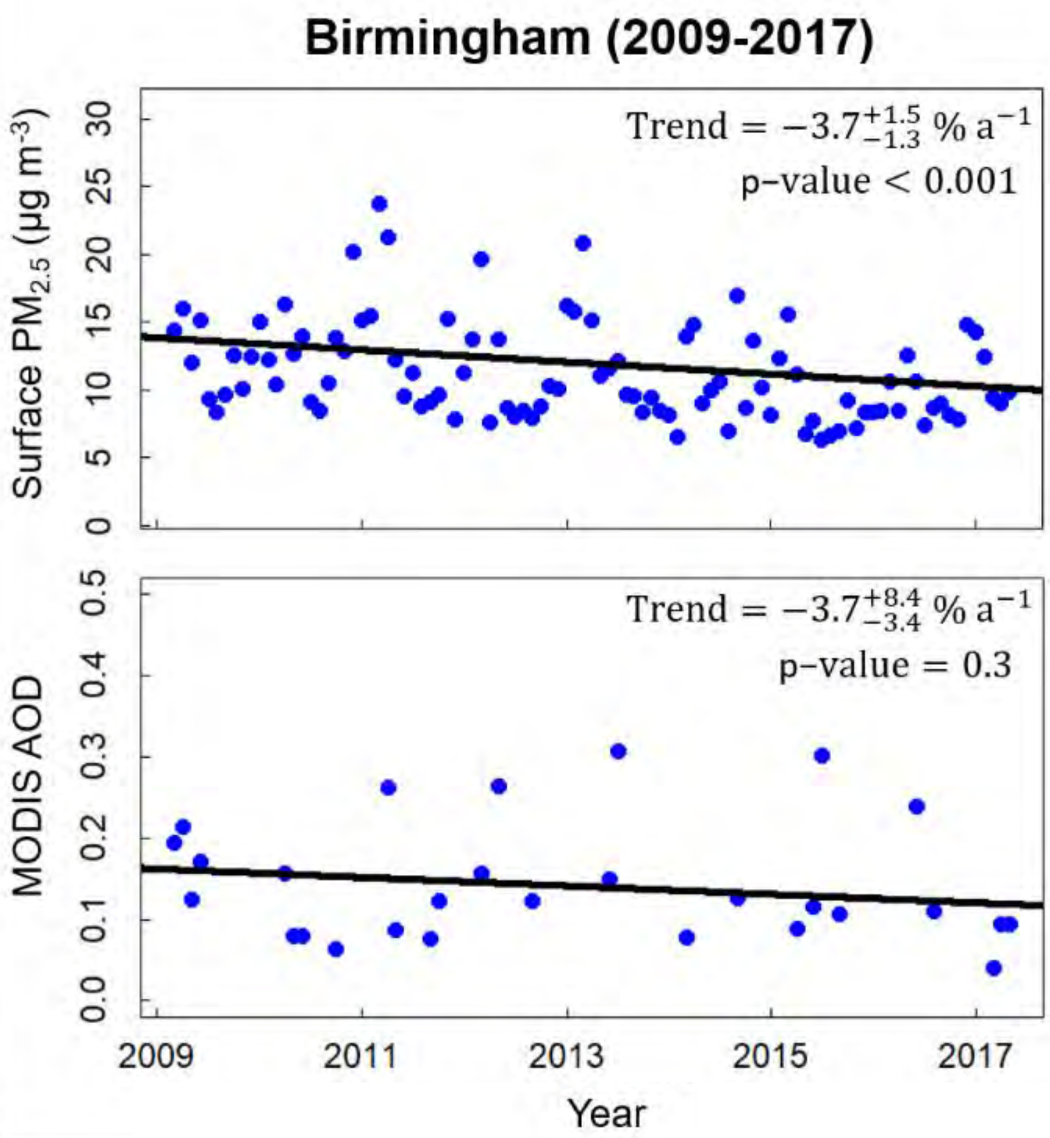
Satellite observations of AOD reproduce long-term trends in $PM_{2.5}$

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]

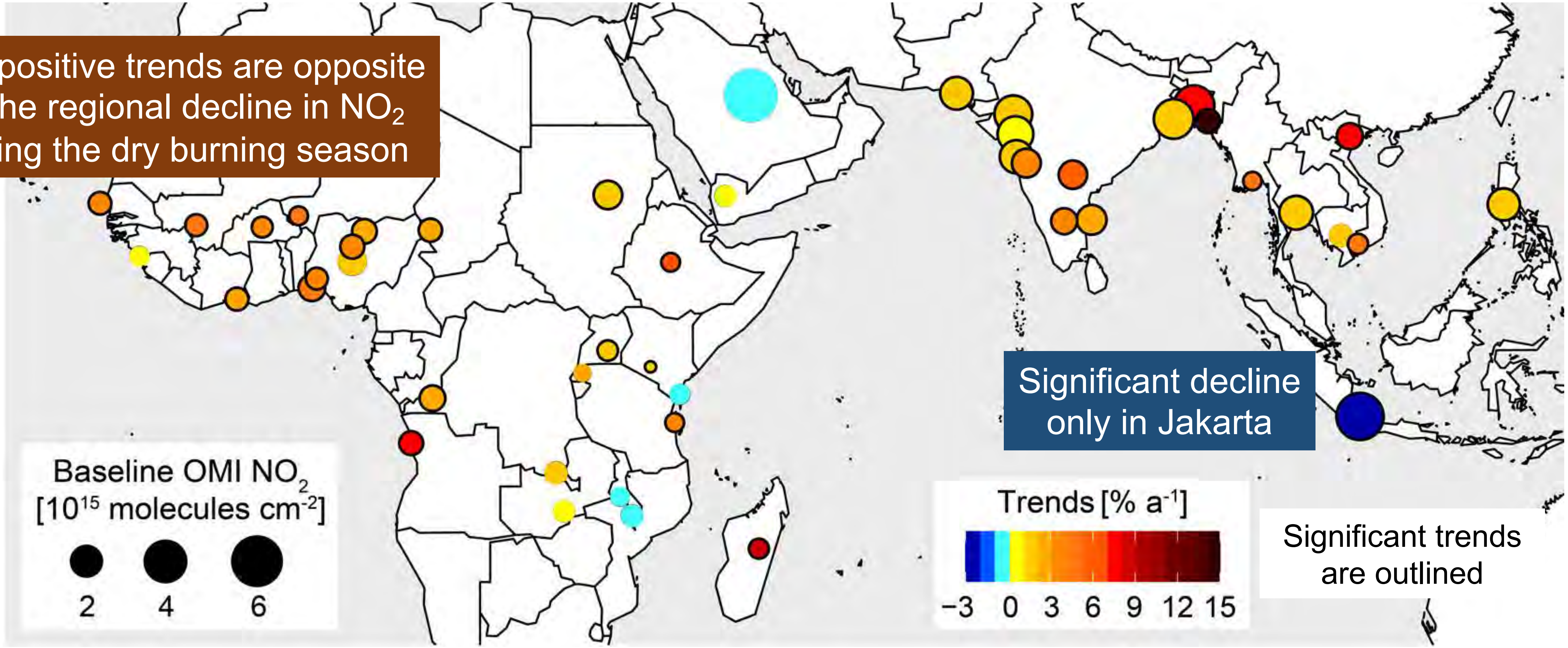


[Vohra et al., *ACP*, 2021]

Trends in NO_2 in tropical future megacities in 2005-2018

NO_2 increases in 41 cities by 0.1-14.1 % a^{-1}

Our positive trends are opposite to the regional decline in NO_2 during the dry burning season



Significant decline only in Jakarta

Significant trends are outlined

Steep increases in NO_2 with implications for ozone formation and aerosol nitrate

[Vohra et al., *Sci. Adv.*, 2022]

Trends in ozone production regimes in 2005-2018

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

$HCHO/NO_2$

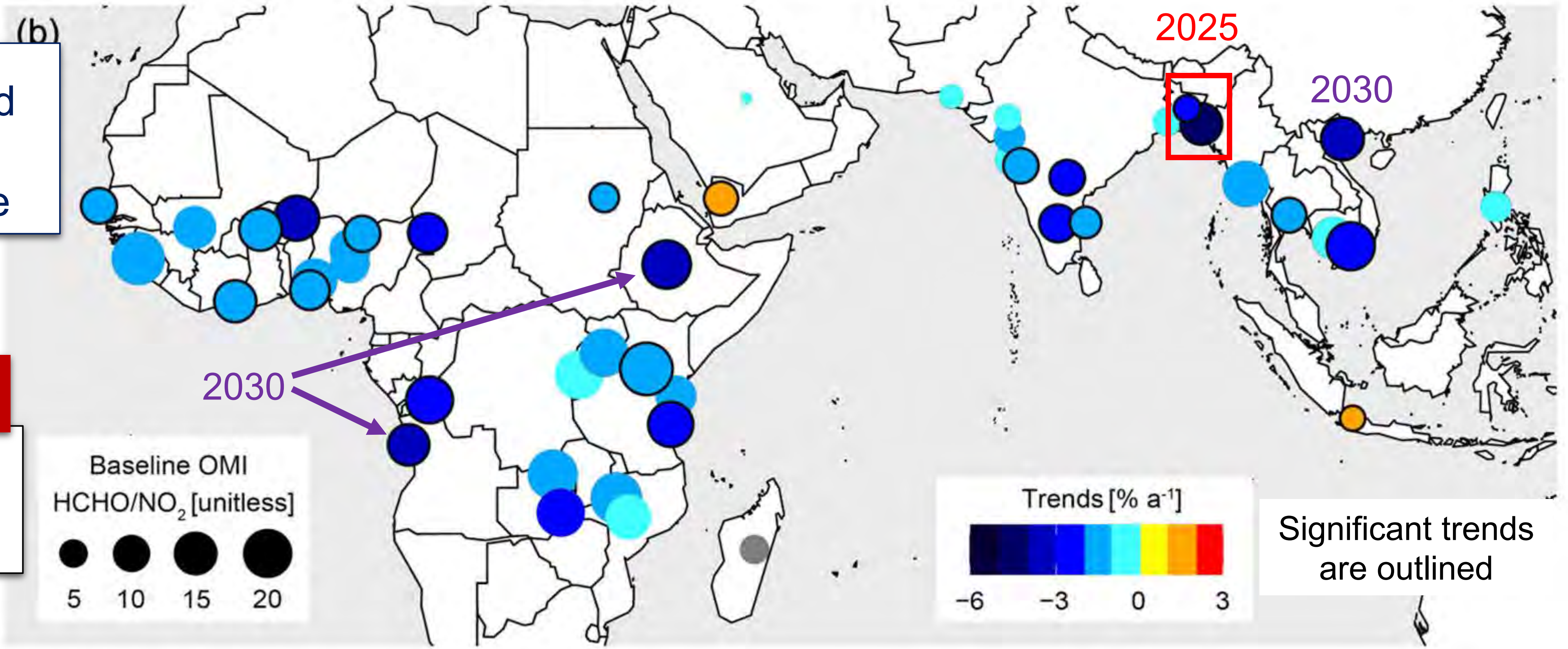
< 1 ⇒ NO_X-saturated
~ 1-4 ⇒ transition
> 4 ⇒ NO_X-sensitive

[Martin et al., 2004; Jin et al., 2015]

Limitation

Threshold for regime transition depends on local oxidation regime

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

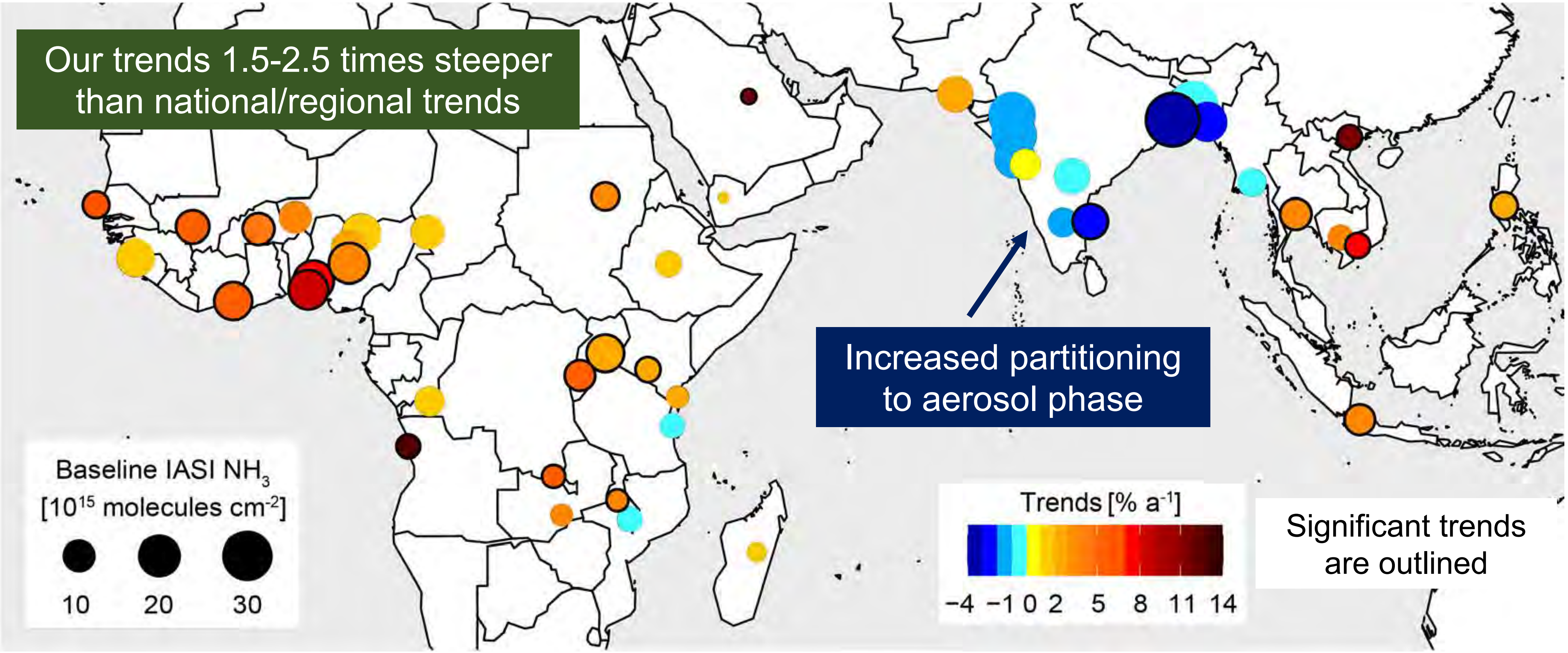


All cities except Riyadh are in NO_x-sensitive regime; Jakarta and Sana'a will remain in NO_x-sensitive regime; Gradual transition to NO_x-saturated regime may occur as early as 2025

[Vohra et al., *Sci. Adv.*, 2022]

Trends in NH_3 in tropical future megacities in 2008-2018

NH_3 increases in cities in all regions except the Indian subcontinent

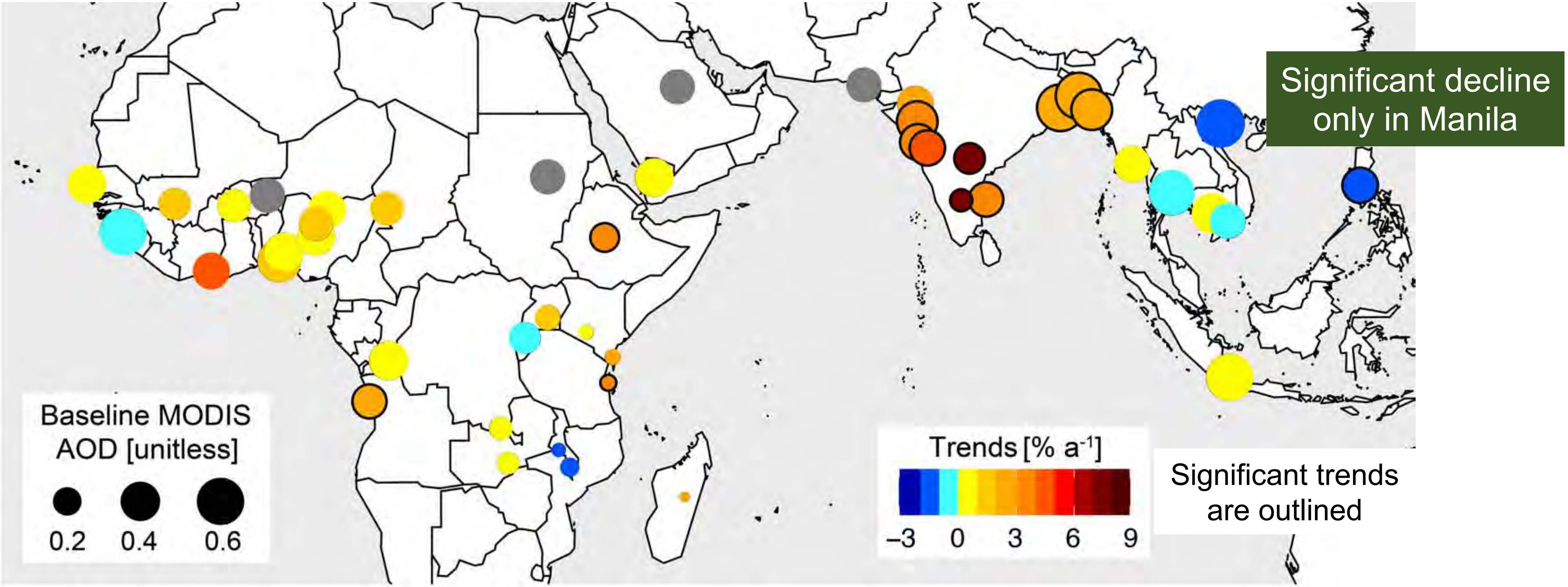


Steep increasing trends in cities in Africa and Southeast Asia may reflect increasing urban sources of NH_3

[Vohra et al., *Sci. Adv.*, 2022]

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

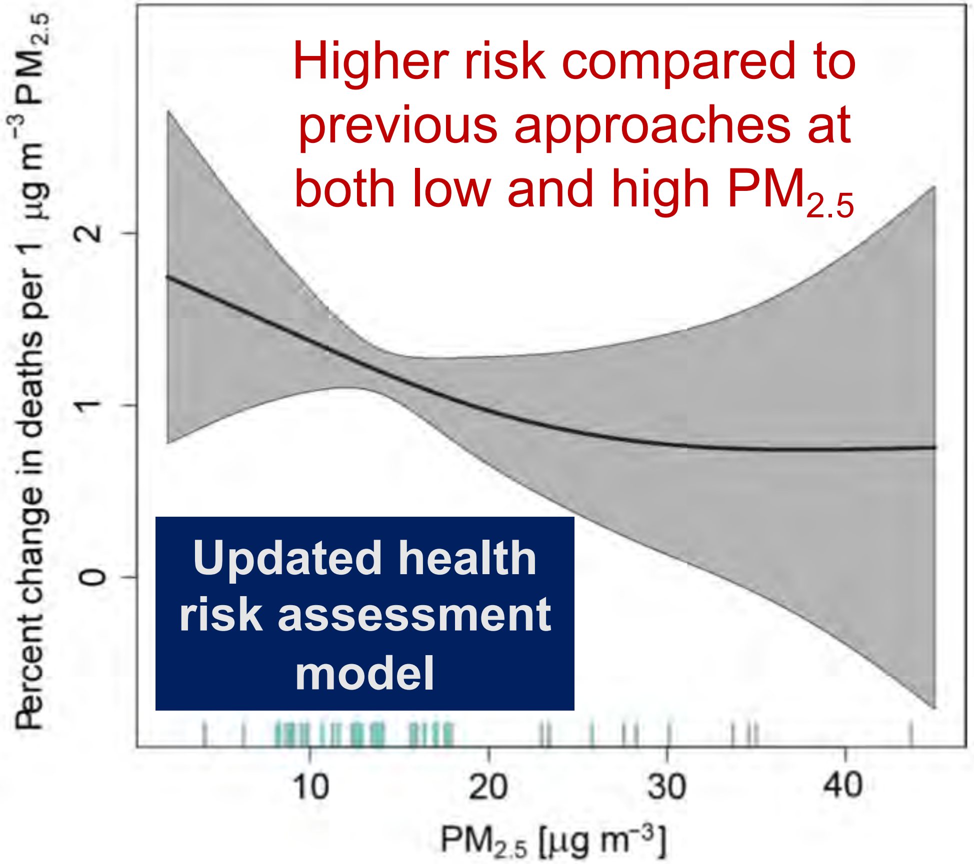


The large increase in South Asian cities is driven by an increase in $PM_{2.5}$ precursor emissions and not desert dust

[Vohra et al., *Sci. Adv.*, 2022]

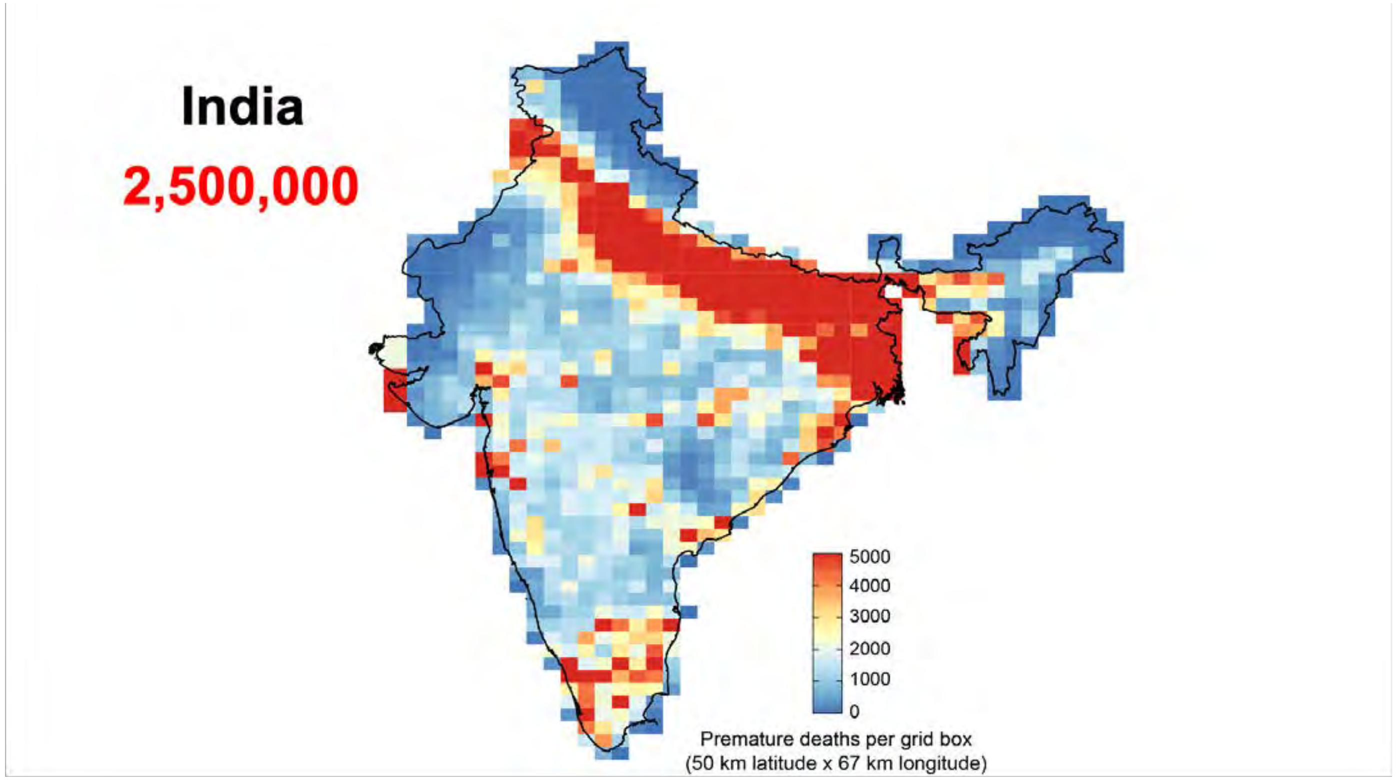
Determine premature mortality from exposure to $PM_{2.5}$

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



[Vodonos et al., 2018]

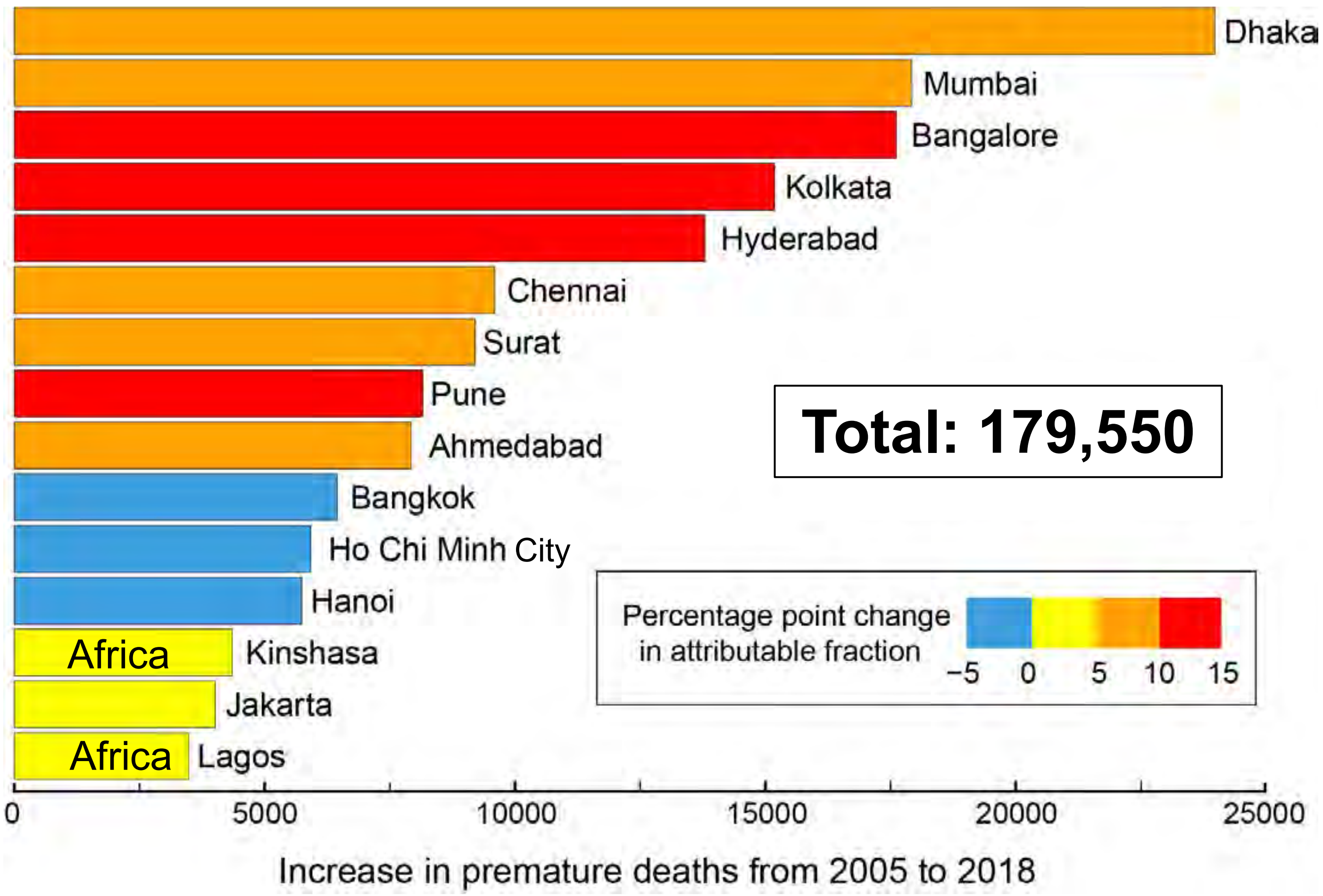
Our premature mortality estimates are 3 times higher than previous studies



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

[Vohra et al., *Environ. Res.*, 2021]

Severe health burden in tropical future megacities

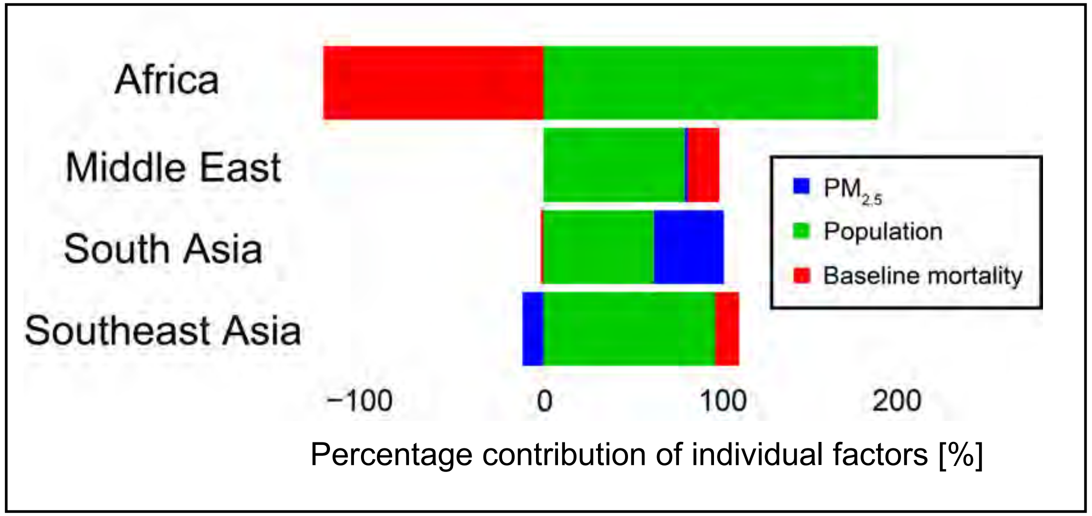


Premature mortality from long-term $PM_{2.5}$ exposure

2005 **290,000** (95% CI: 200,000 to 370,000)

62% ▲

2018 **470,000** (95% CI: 70,000 to 870,000)



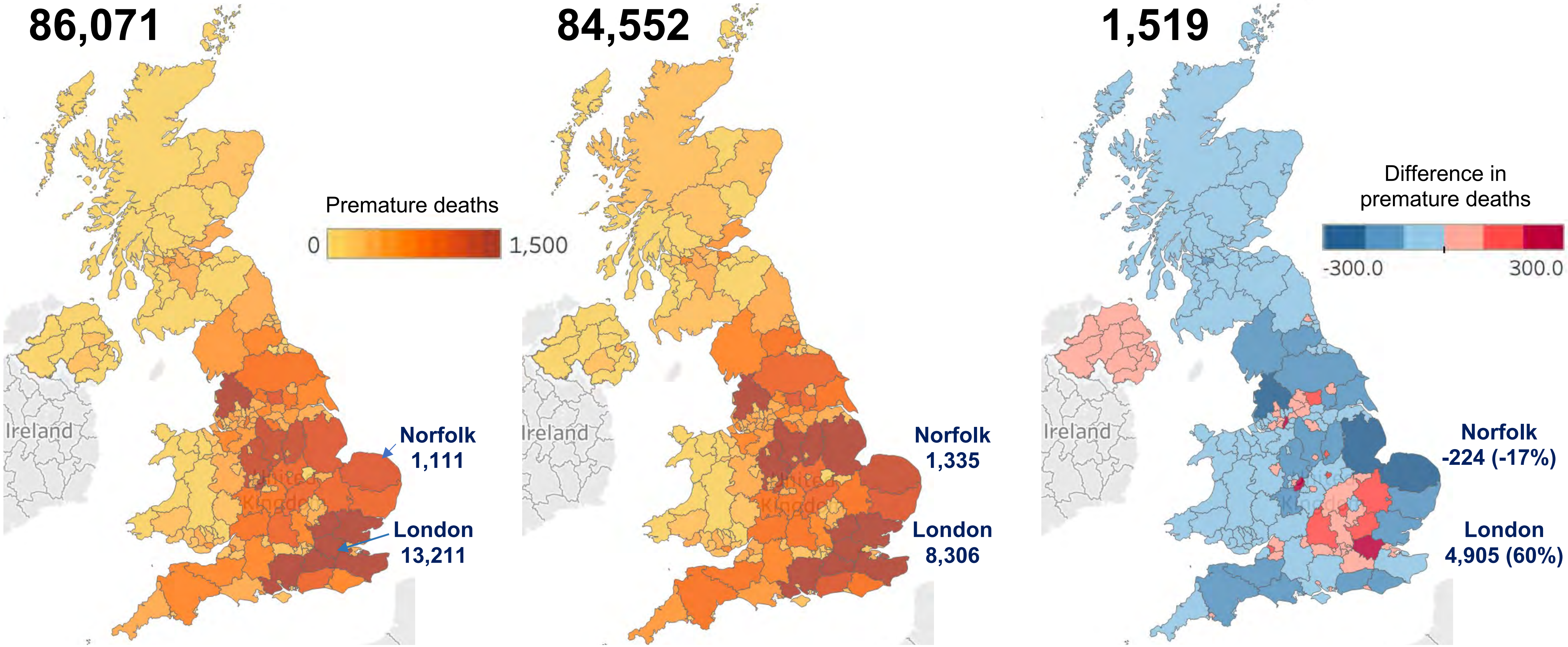
Largest increases in premature mortality in cities in Asia

Effects of $PM_{2.5}$ on health in African cities countered by decline in baseline mortality rate

[Vohra et al., *Sci. Adv.*, 2022]

Implications of national baseline mortality rates on health burden

A) UK-wide baseline mortality rate | B) County-level baseline mortality rate | Premature mortality difference (A-B)



We overestimate premature deaths in densely populated regions and so we need sub-national baseline mortality rates

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 $PM_{2.5}$
- 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** from 2005 to 2018 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, *Science Advances*, doi:10.1126/sciadv.abm4435, 2022.

Interactive dashboards

Air quality trends

Premature deaths

Any Questions? Email k.vohra@ucl.ac.uk @kohra_thefog