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

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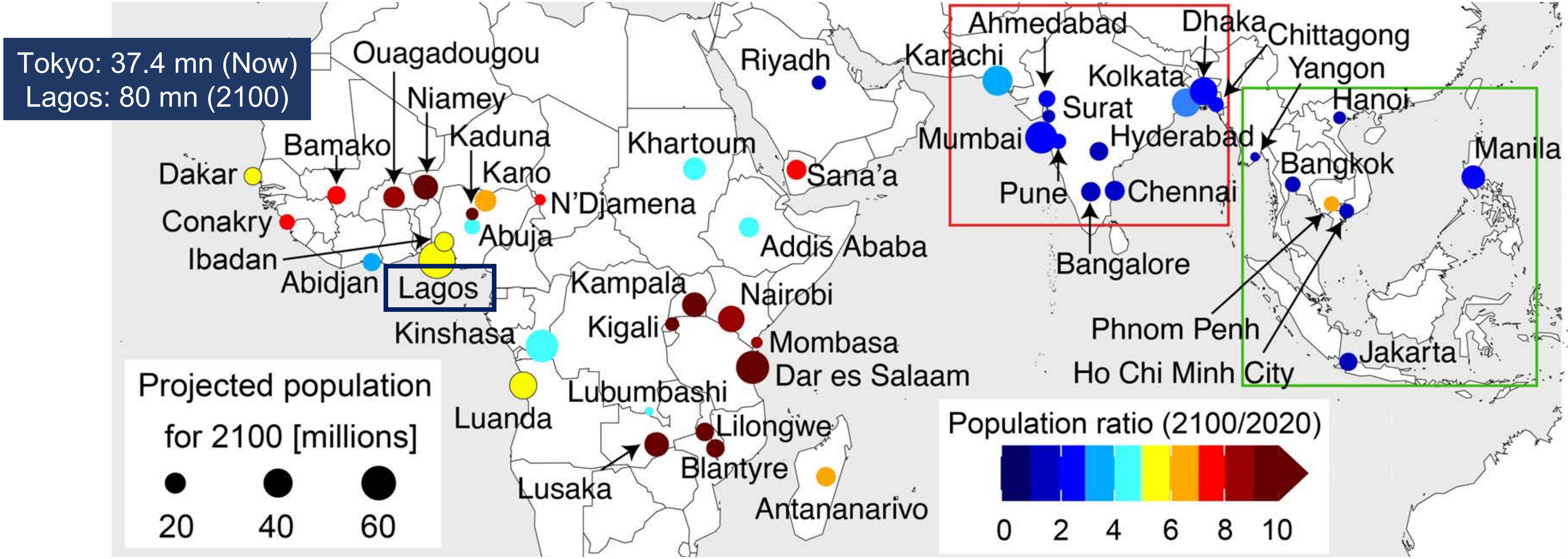
# Tropical cities are experiencing unprecedented growth

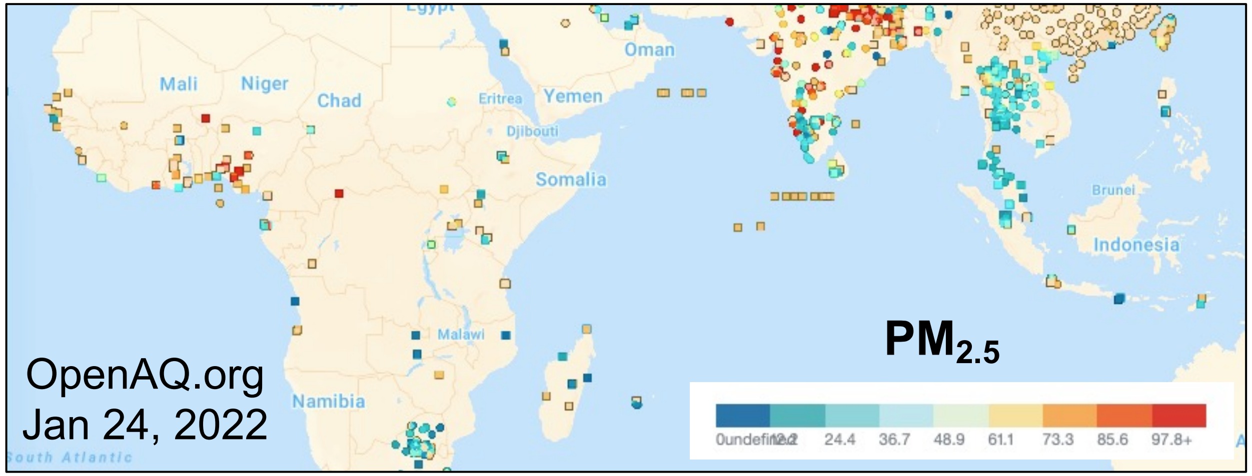
## 46 cities in tropical Asia, Africa and the Middle East will be megacities by 2100

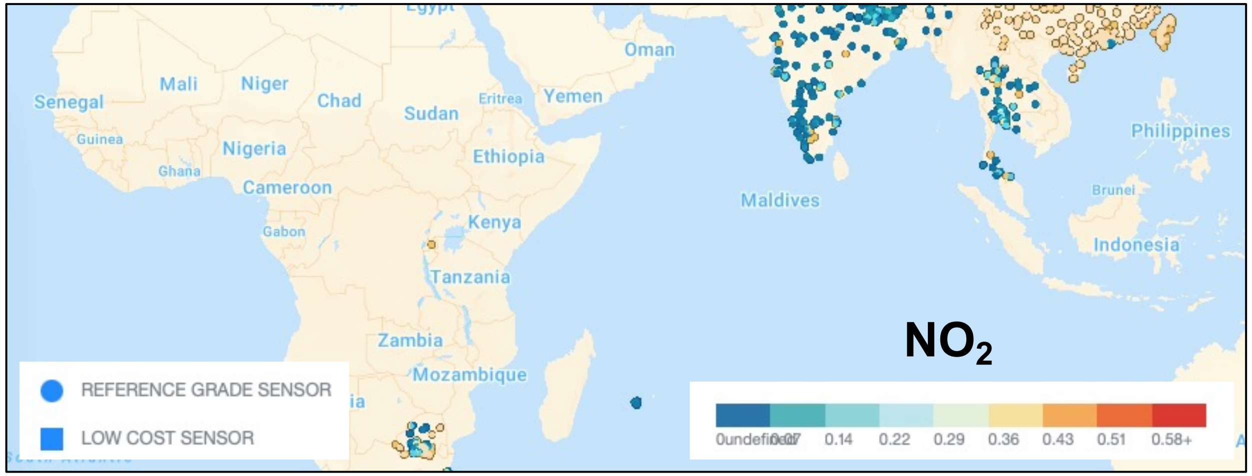



Forecast annual growth rates for 2020-2100: 3-31% in Africa, 0.8-3% in South Asia and 0.5-7% in Southeast Asia [Hoornweg & Pope, 2017]

# Tropical cities are the next frontier in air pollution

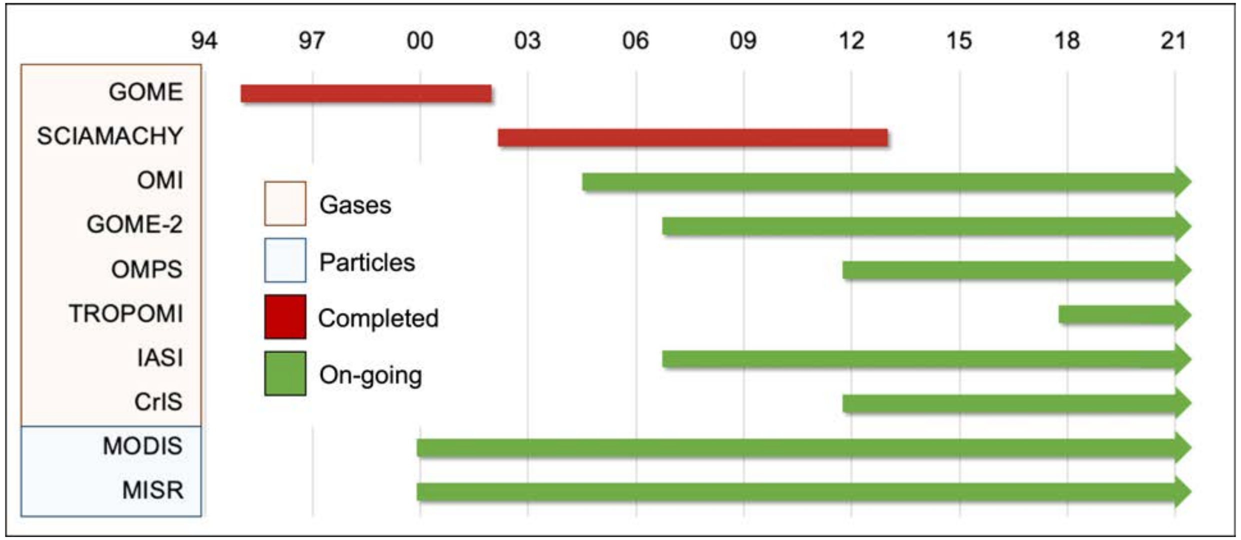
Currently, limited surface monitoring of air pollutants across the tropics




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

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



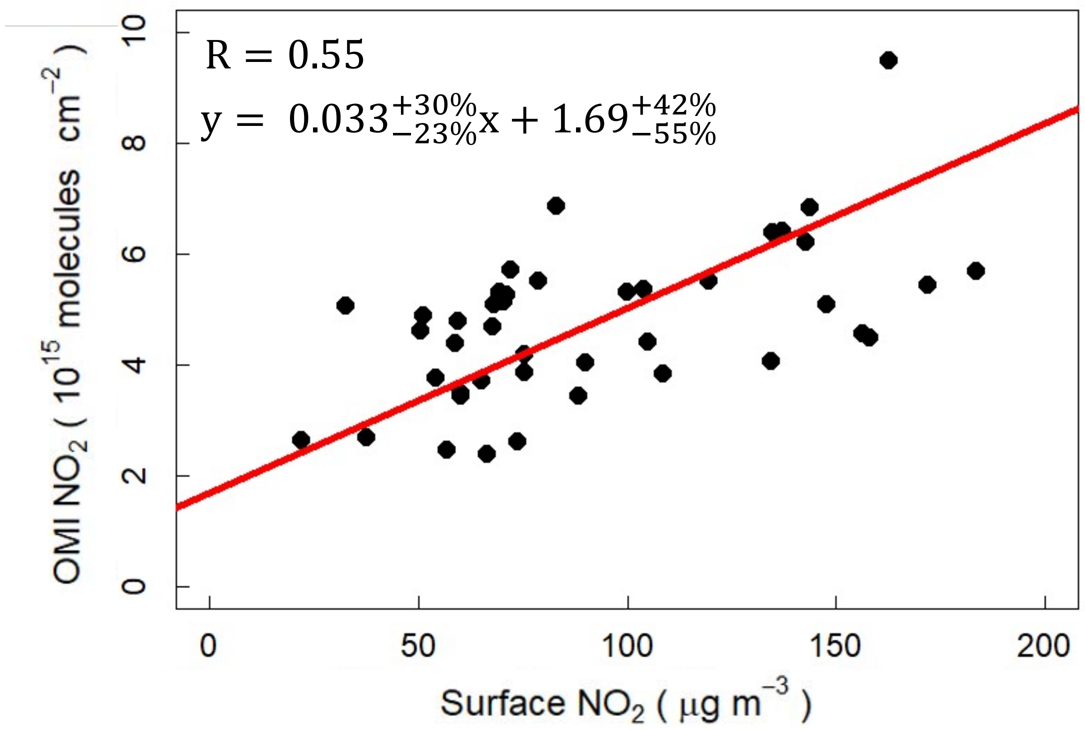

**OMI** for **$NO_2$** and **HCHO** (proxy for NMVOCs)

**IASI** for **$NH_3$**

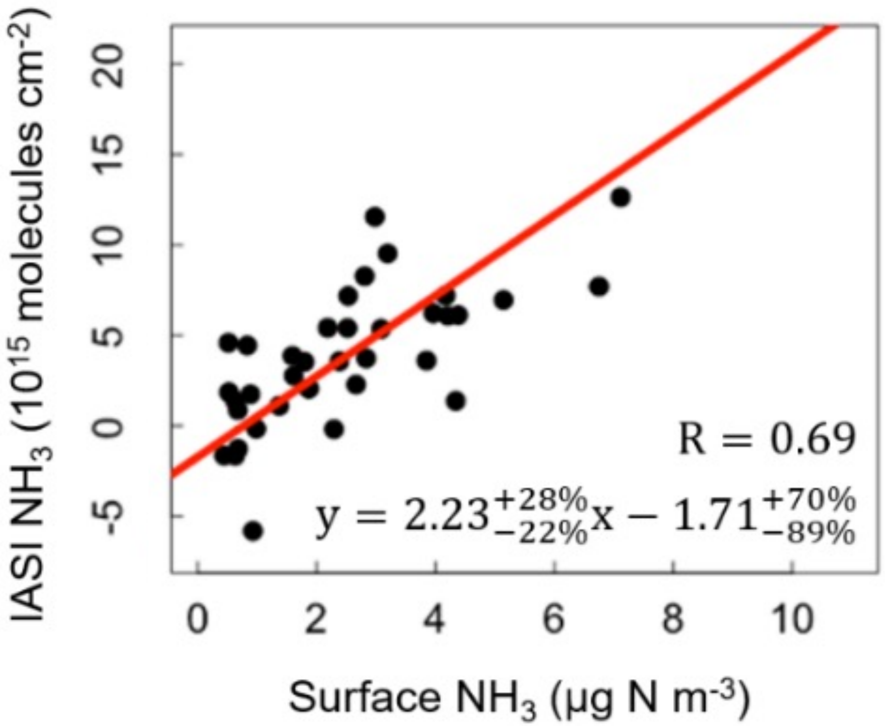
**MODIS** for **AOD** (proxy for $PM_{2.5}$)

# 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)

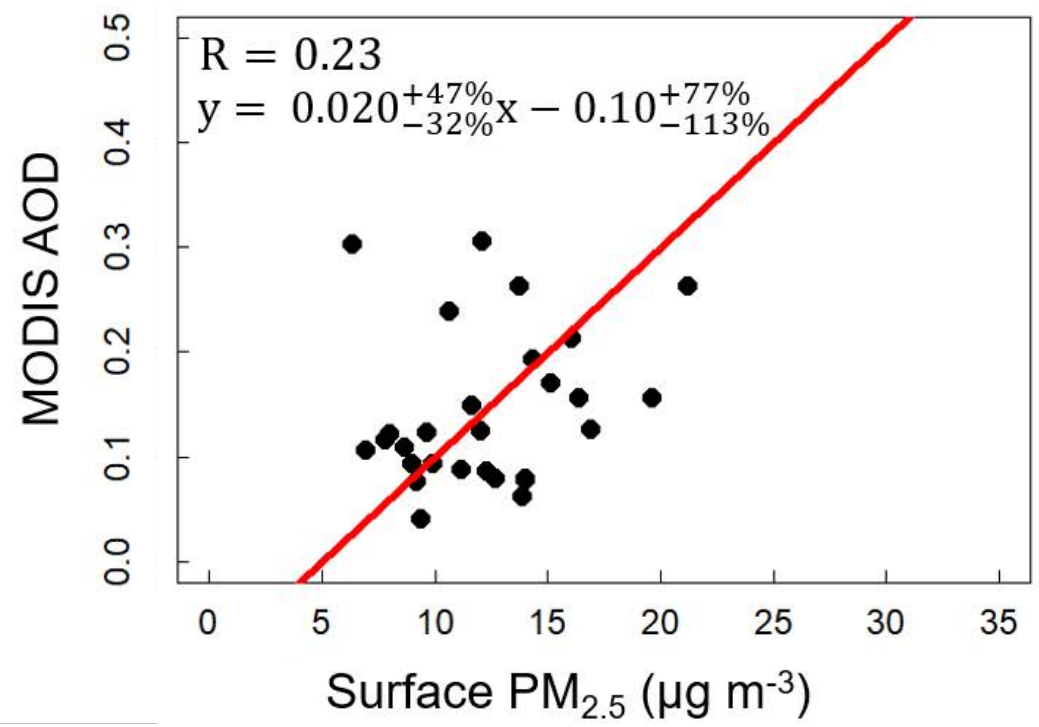



Temporal consistency between satellite and surface measurements of $NO_2$ and $NH_3$

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

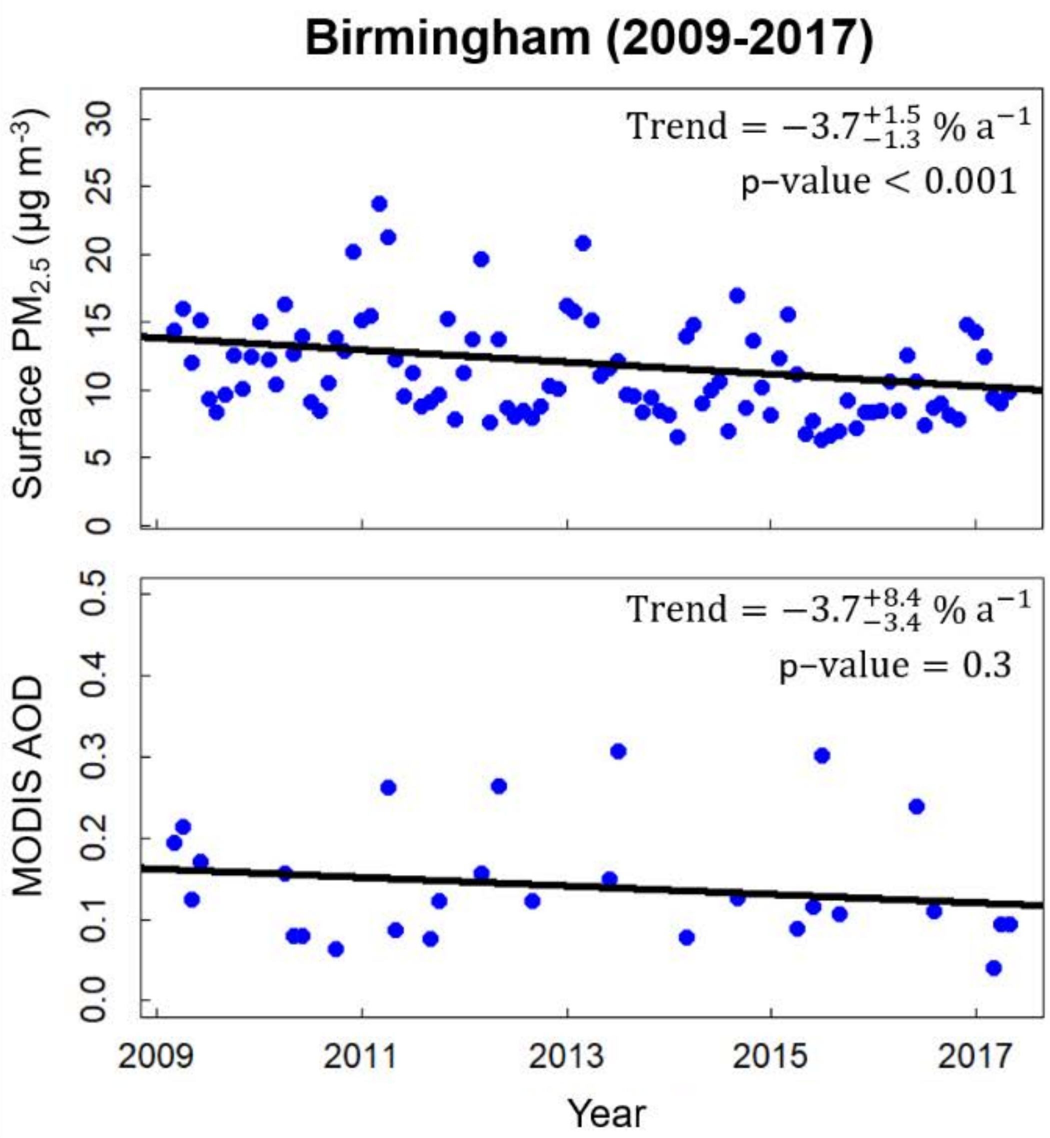
# Satellite observations of AOD reproduce long-term trends in $PM_{2.5}$

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




Complicated by meteorological conditions, aerosol composition & vertical distribution

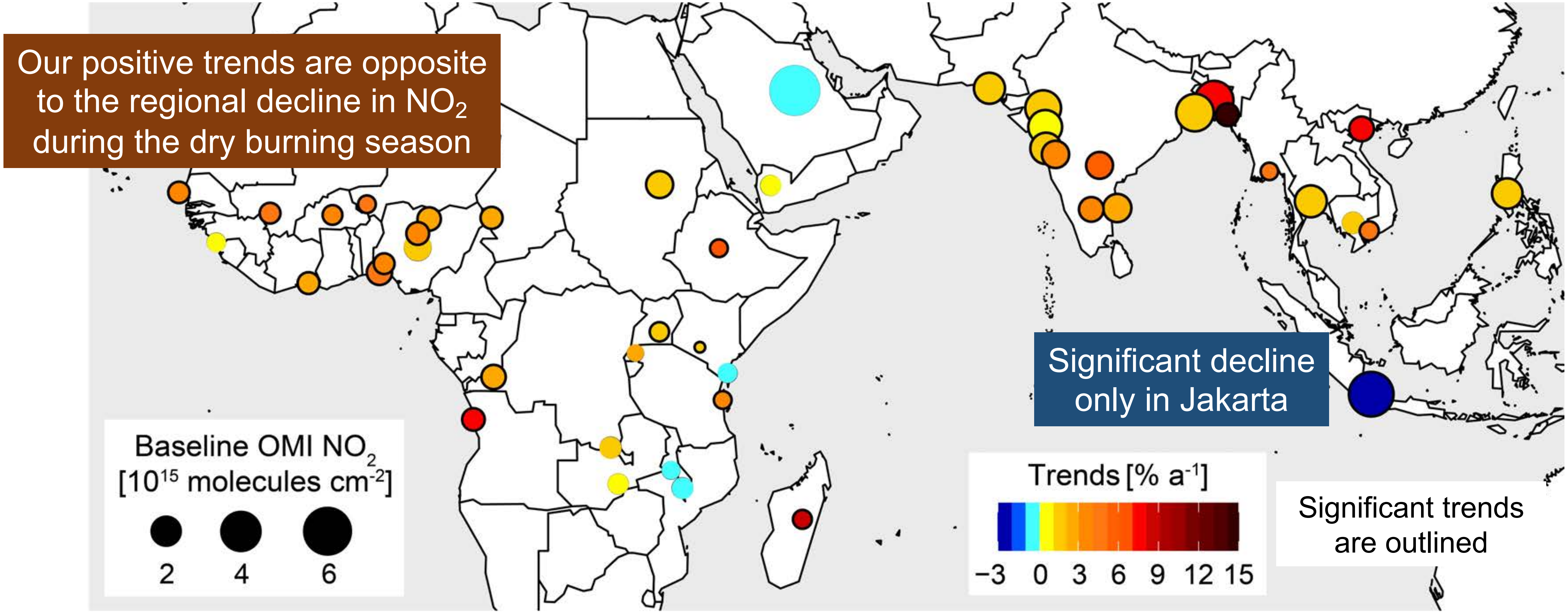
[van Donkelaar et al., 2016; Shaddick et al., 2018]




[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 % $a^{-1}$




Steep increases in $NO_2$ 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/$NO_2$**

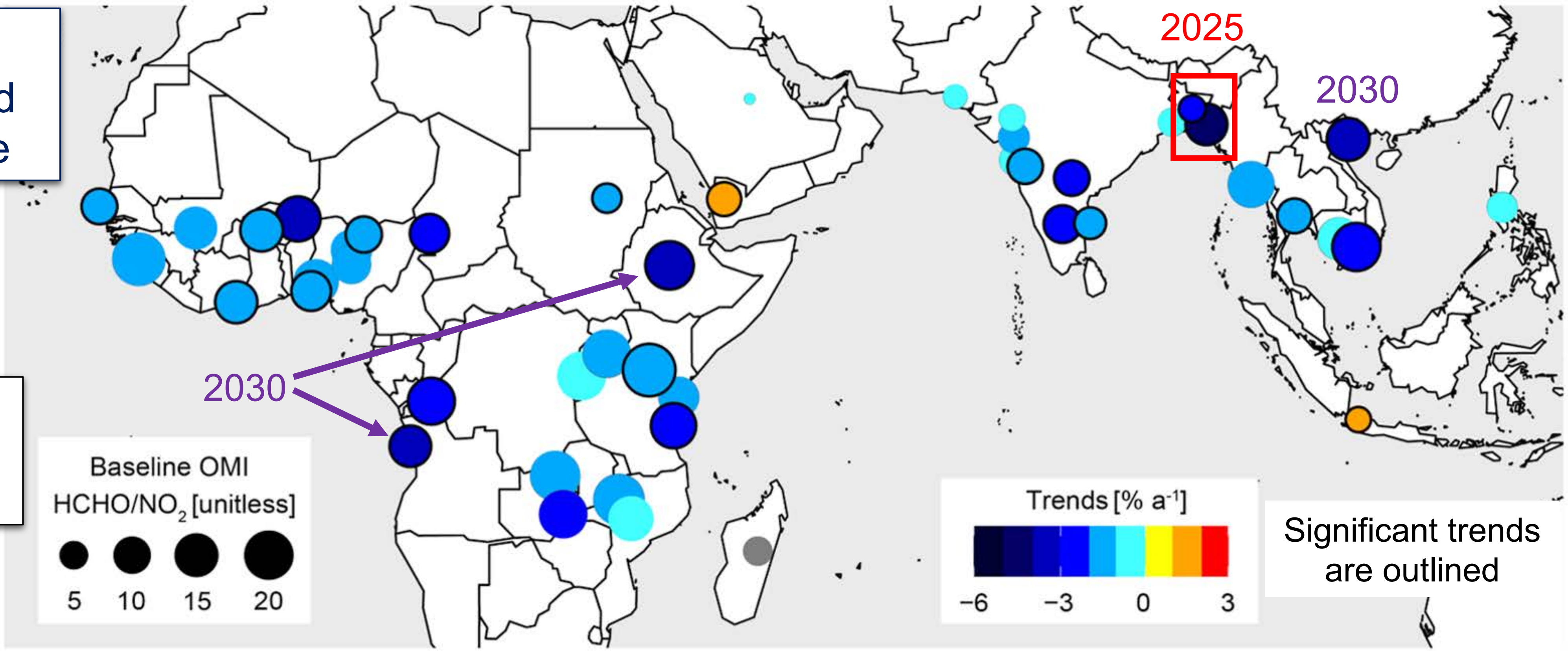
< 1 ⇒ $NO_X$-saturated
> 1 ⇒ $NO_X$-sensitive

[Martin et al., 2004]

**Limitation**

Depends on local oxidation regime

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

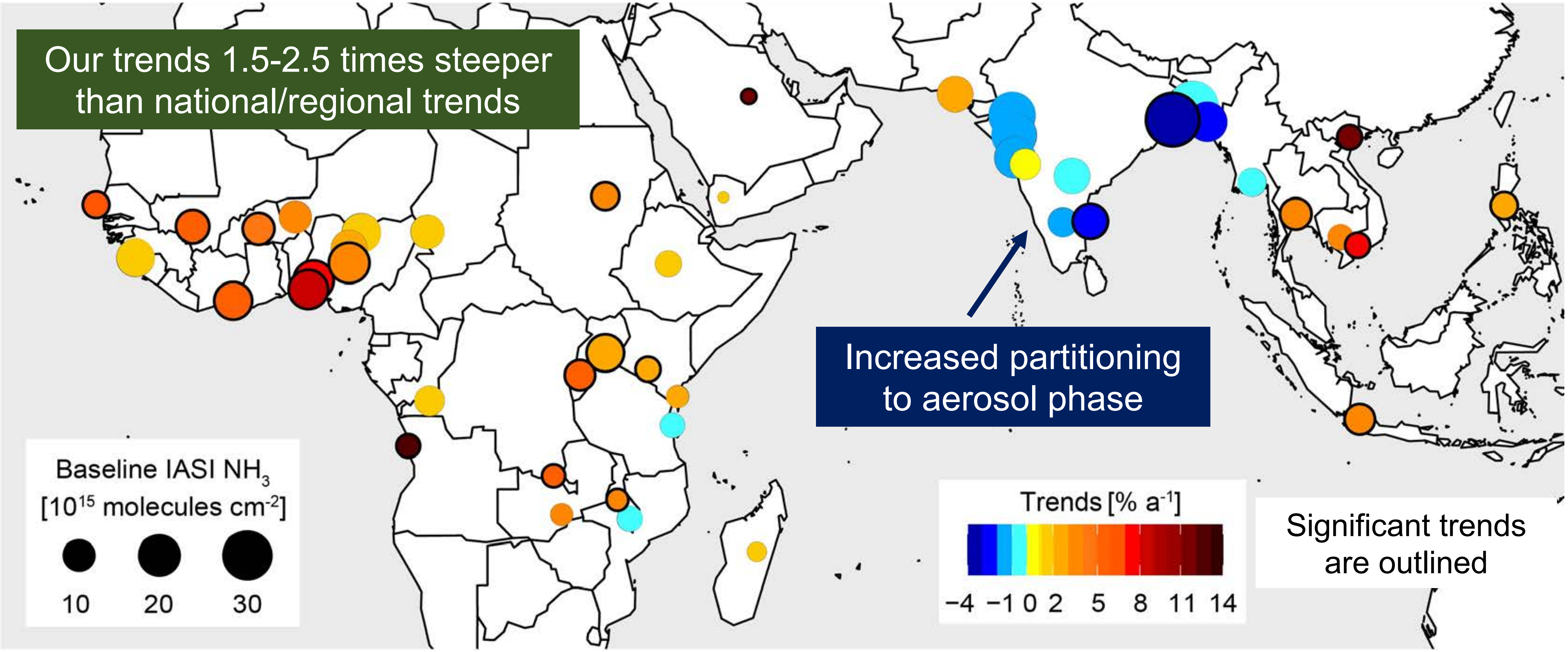



All cities except Jakarta and Sana'a are in $NO_x$-sensitive regime;
Gradual transition to $NO_x$-saturated regime may occur as early as 2025

[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

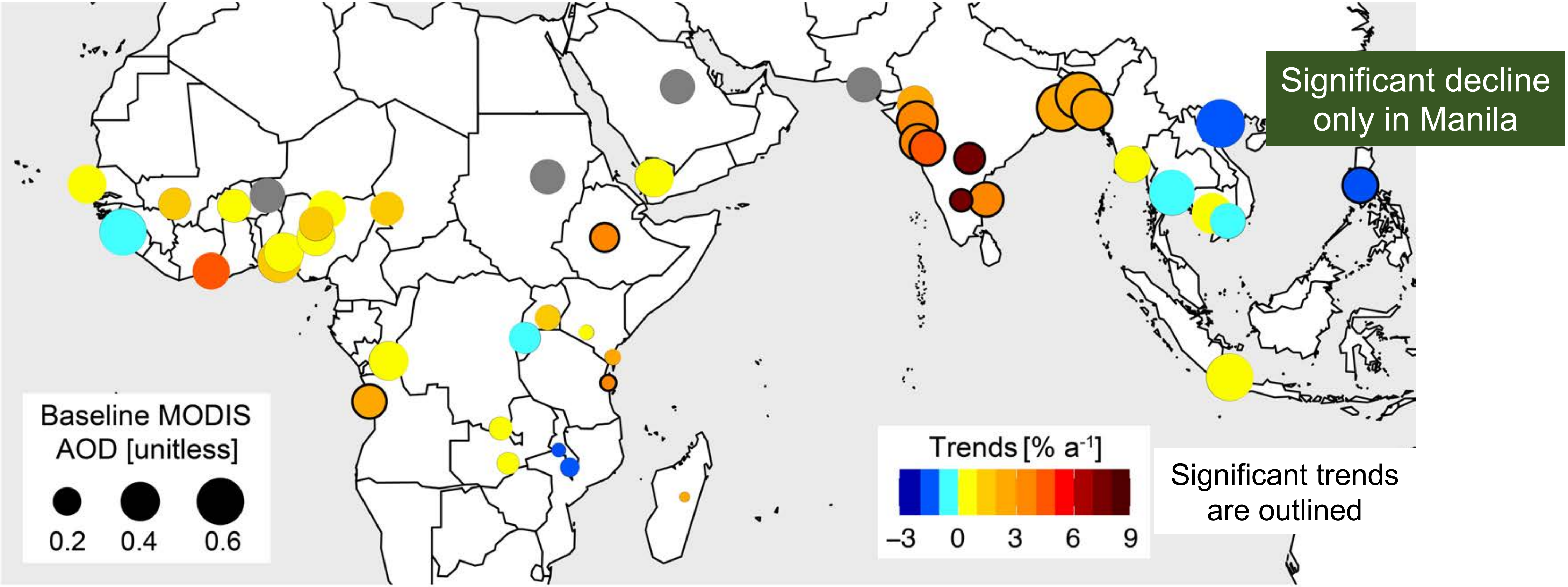



Steep increasing trends in cities in Africa and Southeast Asia may reflect increasing urban sources of $NH_3$

[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

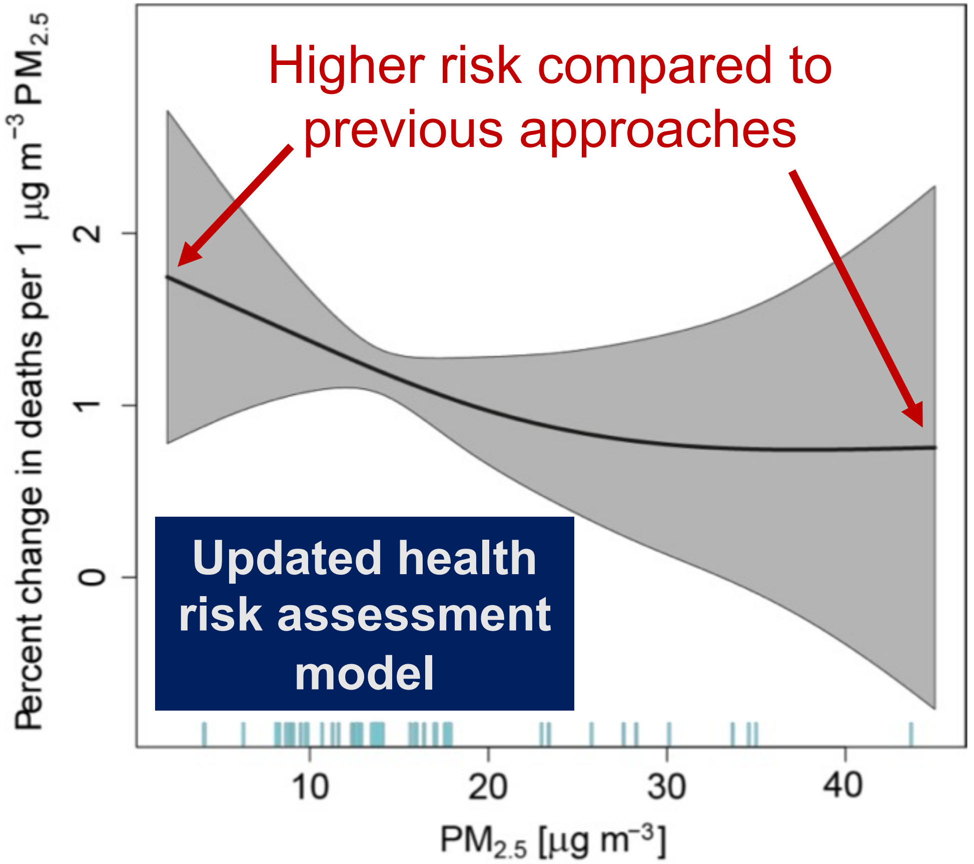



The large increase in South Asian cities is driven by an increase in $PM_{2.5}$ precursor emissions and not desert dust

[Vohra et al., *in review*]

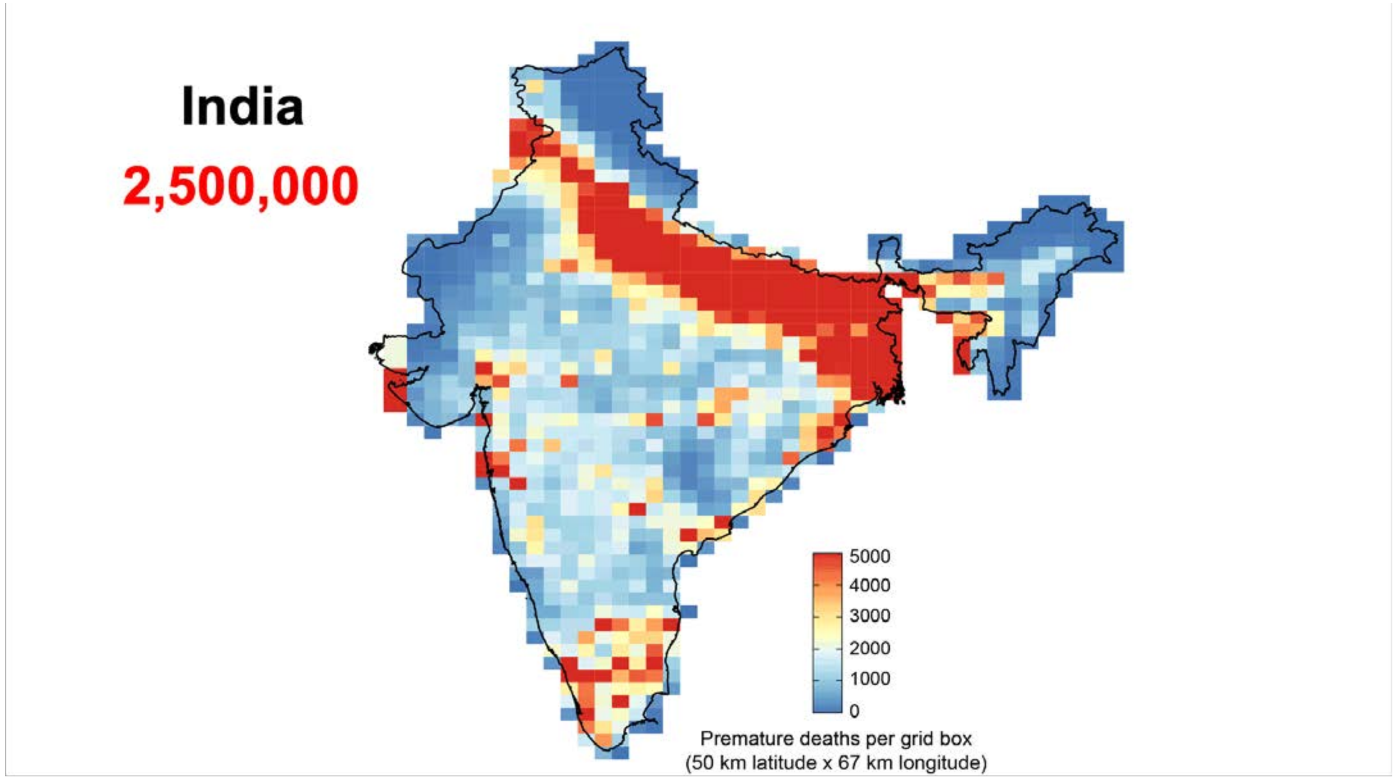
# Determine premature mortality from exposure to $PM_{2.5}$

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




[Vodonos et al., 2018]

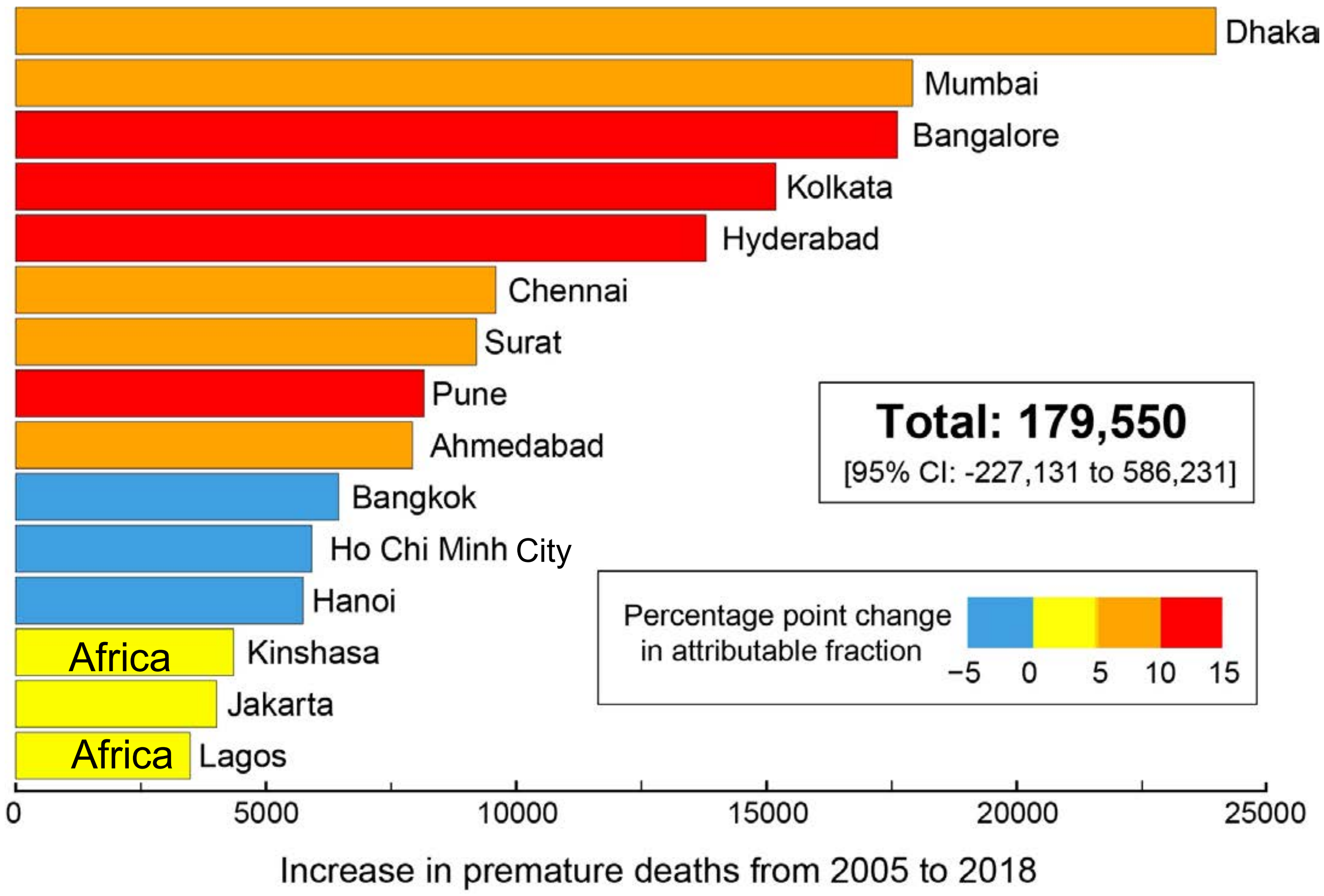
Higher premature mortality estimates than previous studies




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

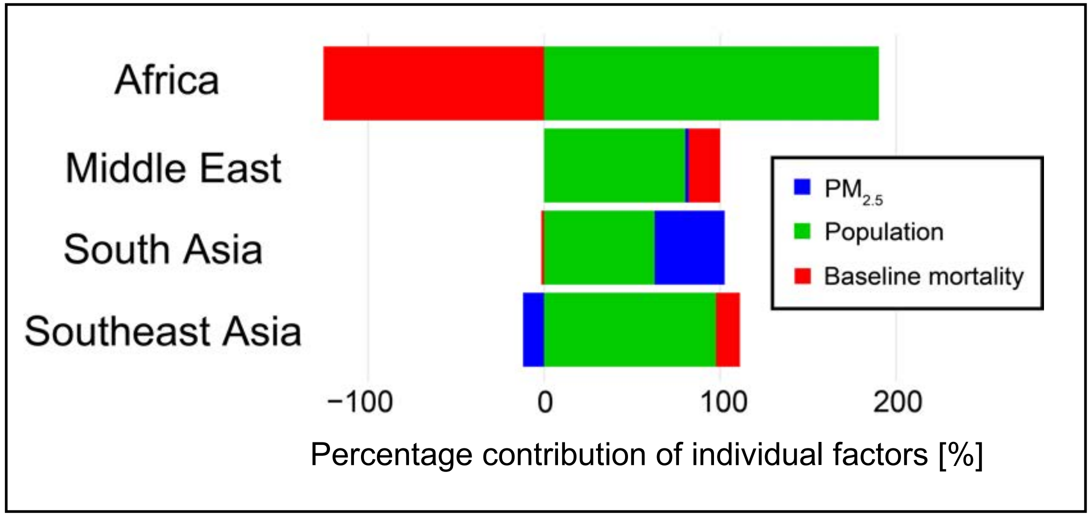



Premature mortality from long-term $PM_{2.5}$ exposure

**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 $PM_{2.5}$
- 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*.

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