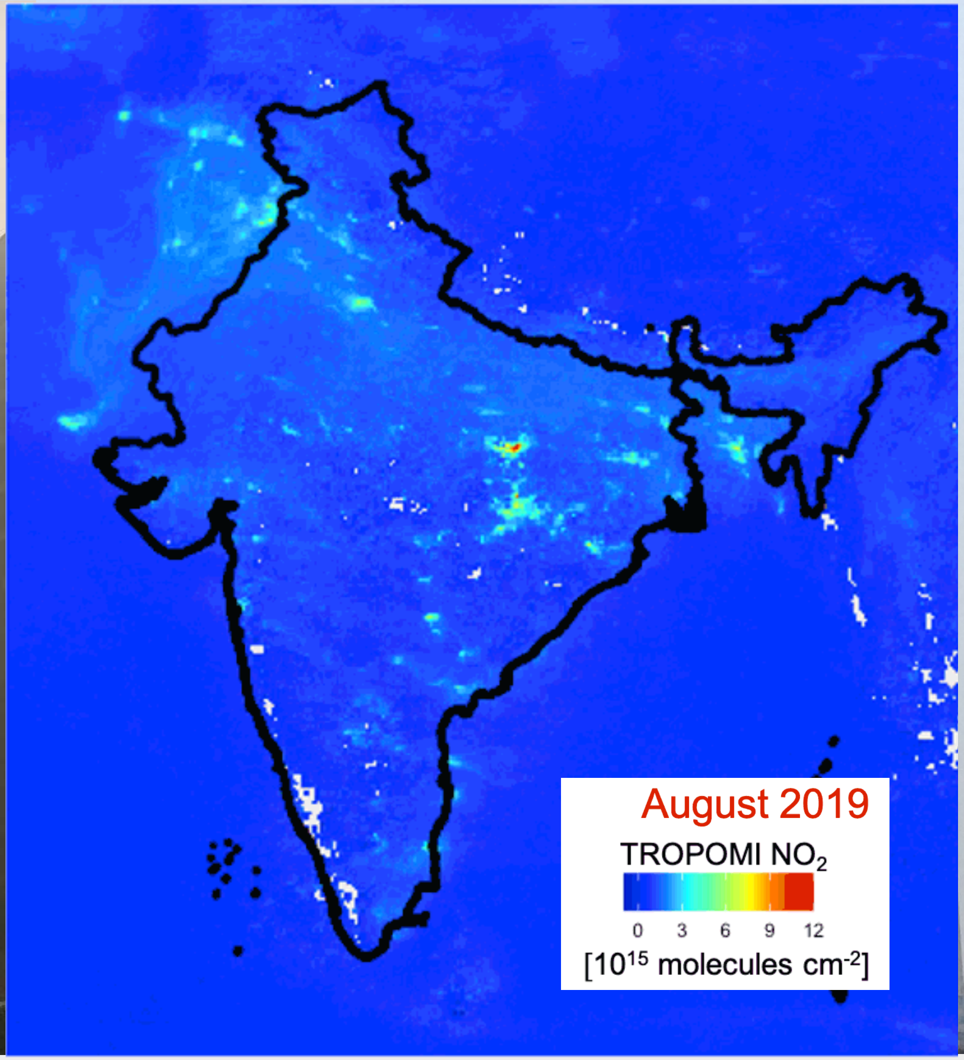
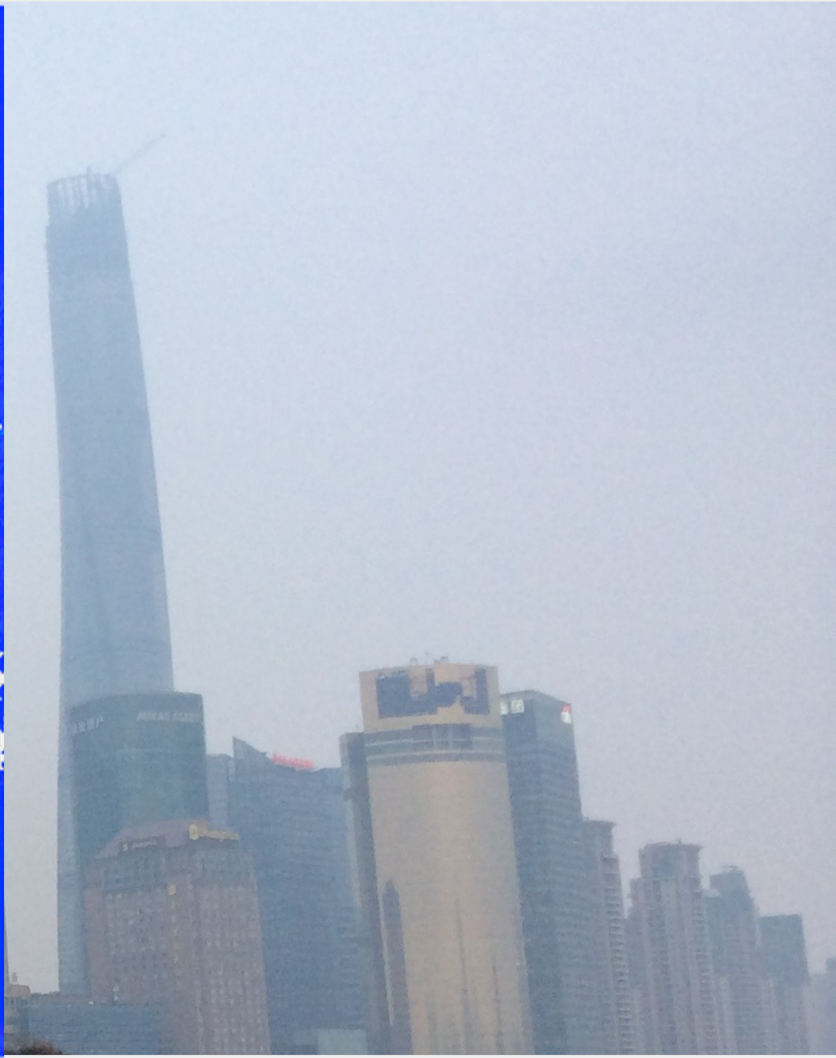
Air quality and health from the city to the global scale



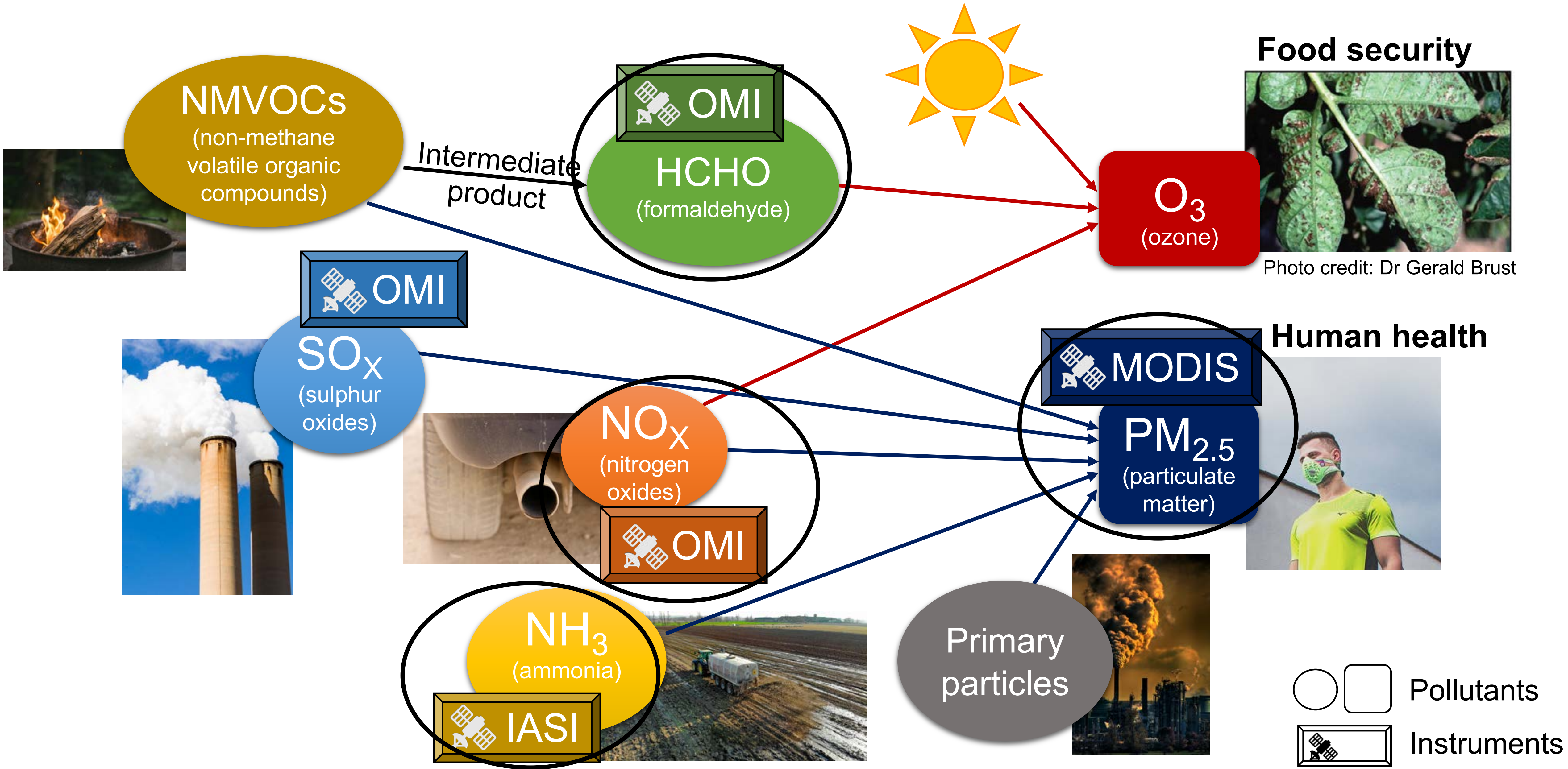


APAC Seminar

Karn Vohra (k.vohra@ucl.ac.uk) @kohra_thefog

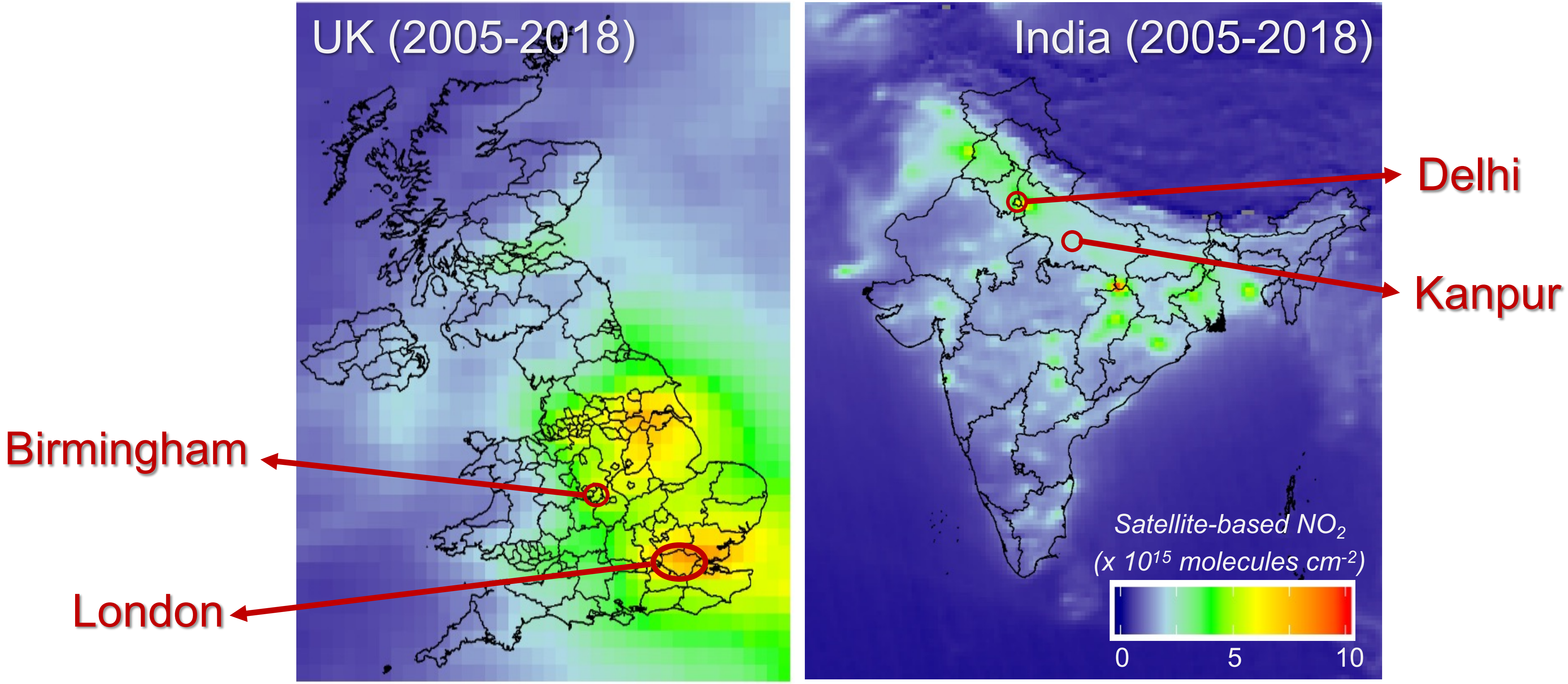
25 November 2021

Satellites help monitor air pollutants



Space-based instruments provide extensive data coverage

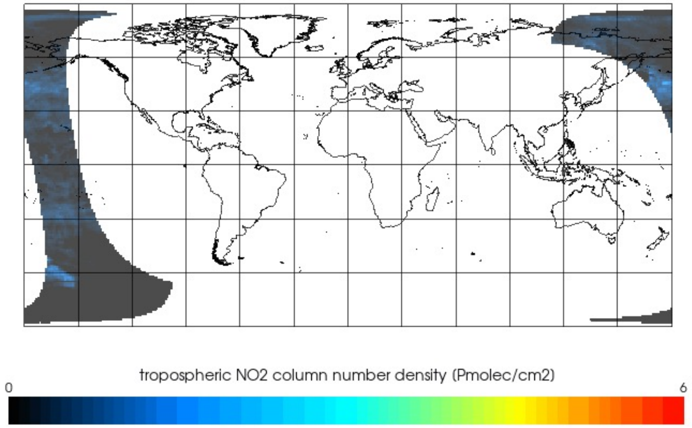
We develop our approach focusing on 4 dynamic cities



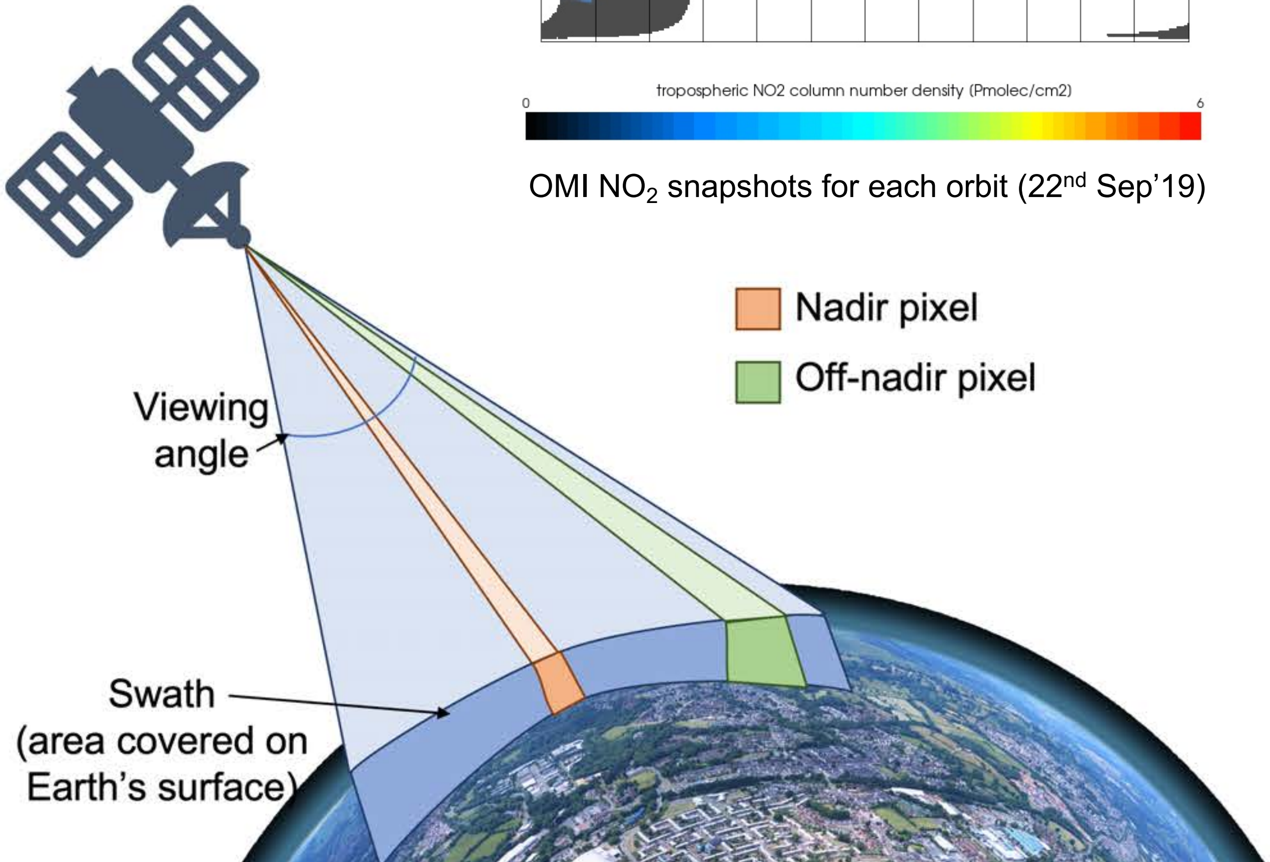
* Maps on different scales

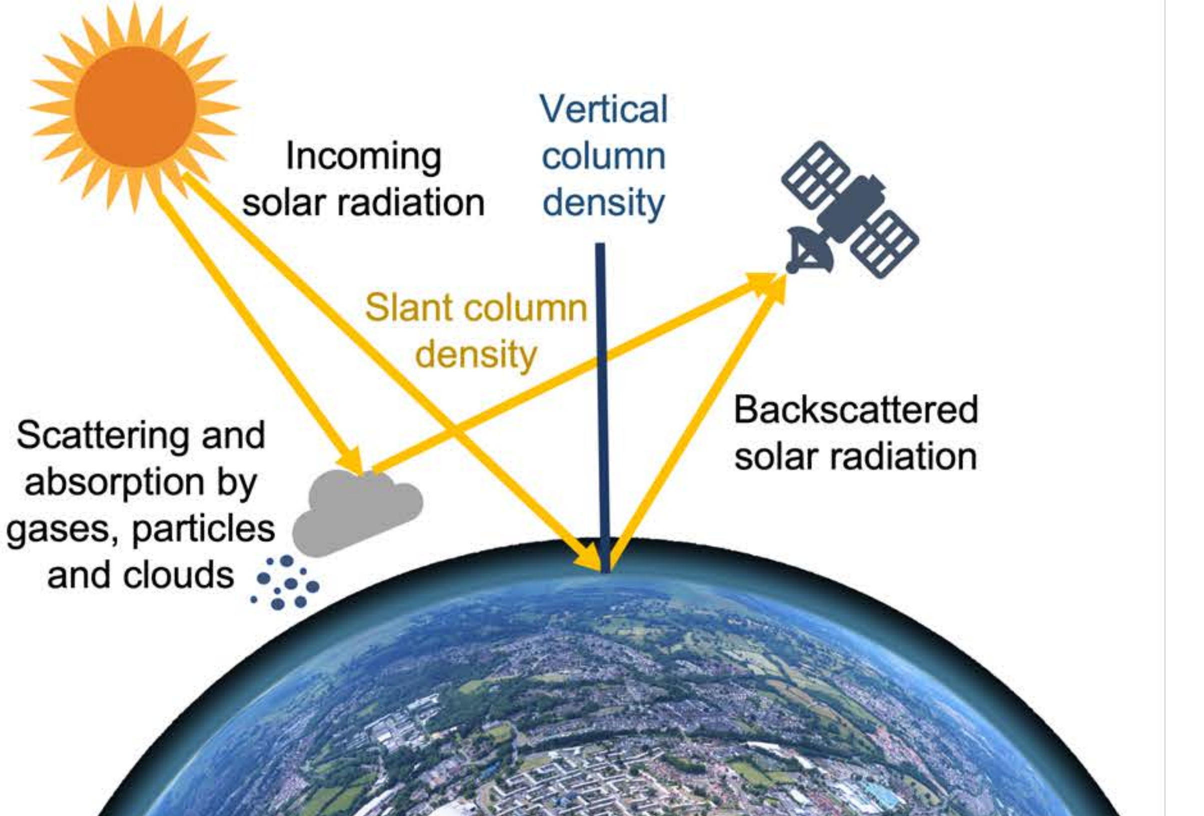
How do satellites make measurements of atmospheric composition?

OMI overpass time : 13h30 local time



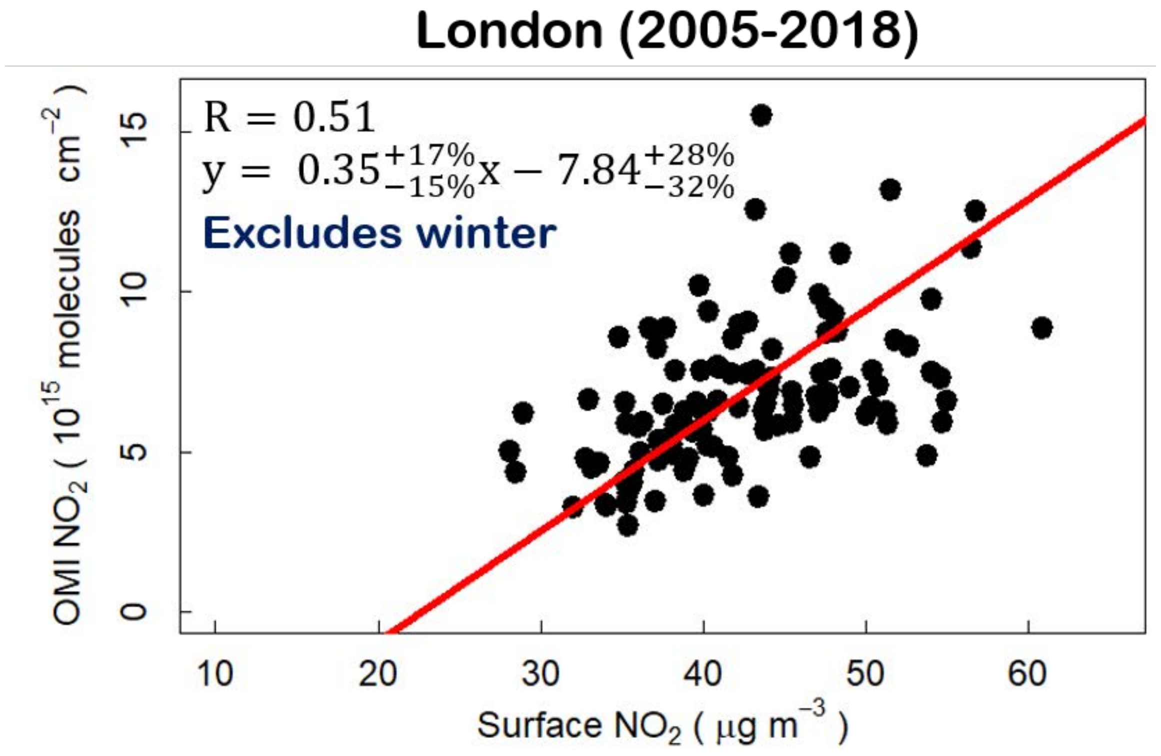
OMI NO_2 snapshots for each orbit (22nd Sep'19)



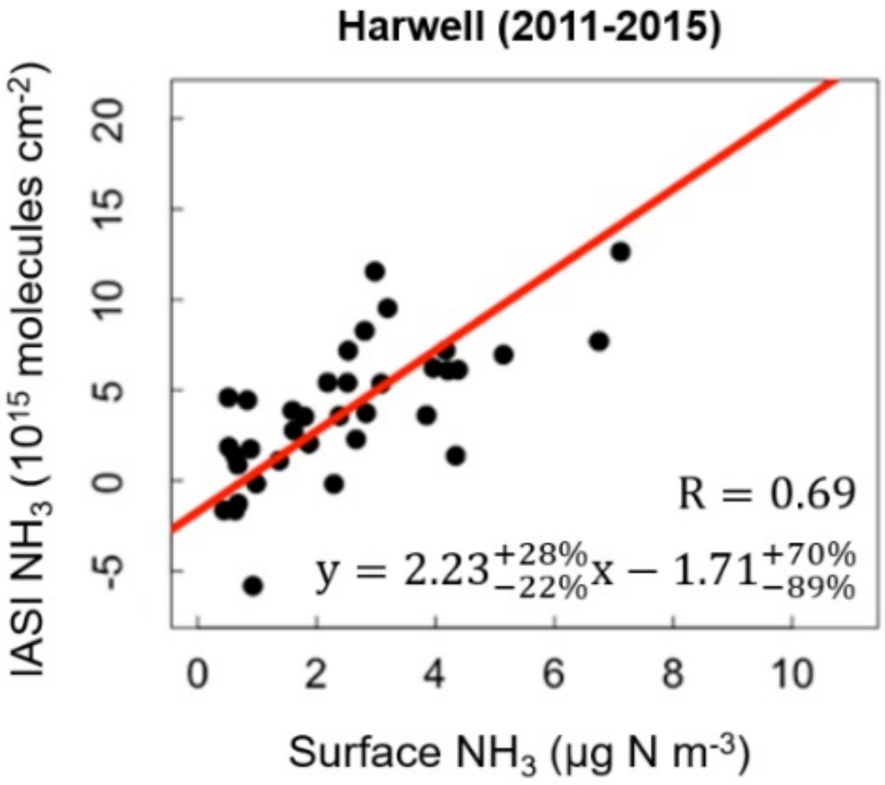


We conduct careful assessment with surface monitors

Satellite versus surface NO_2 in London



Satellite versus surface NH_3 in Harwell

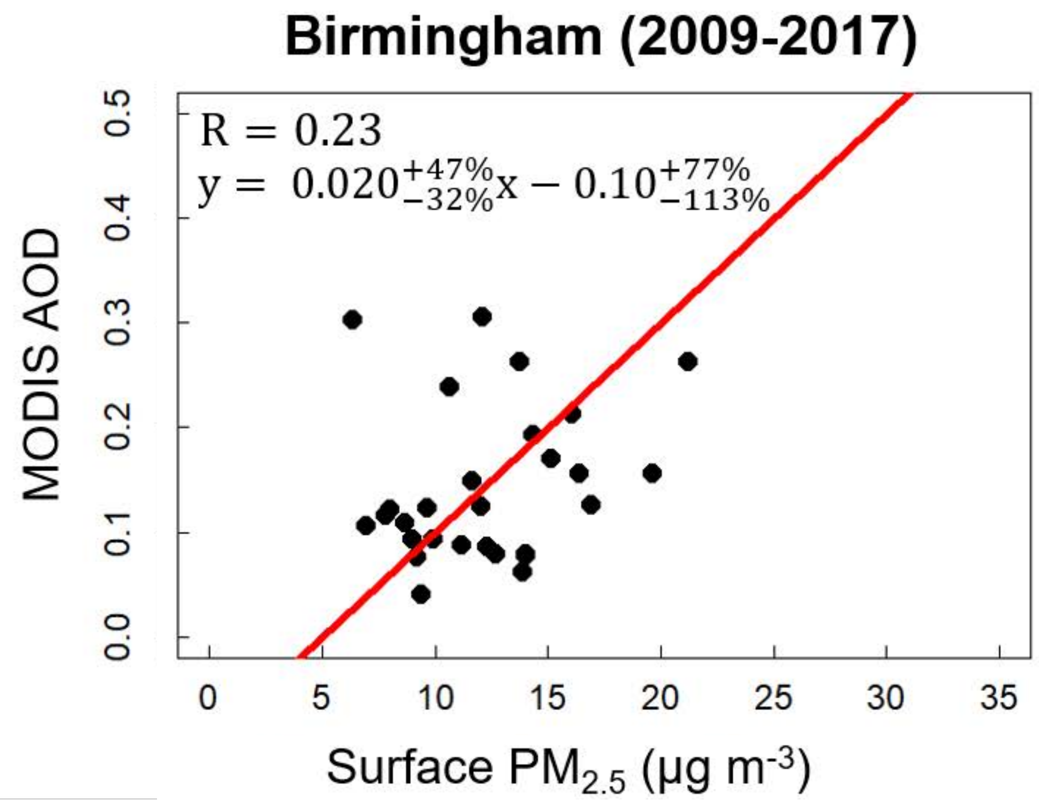


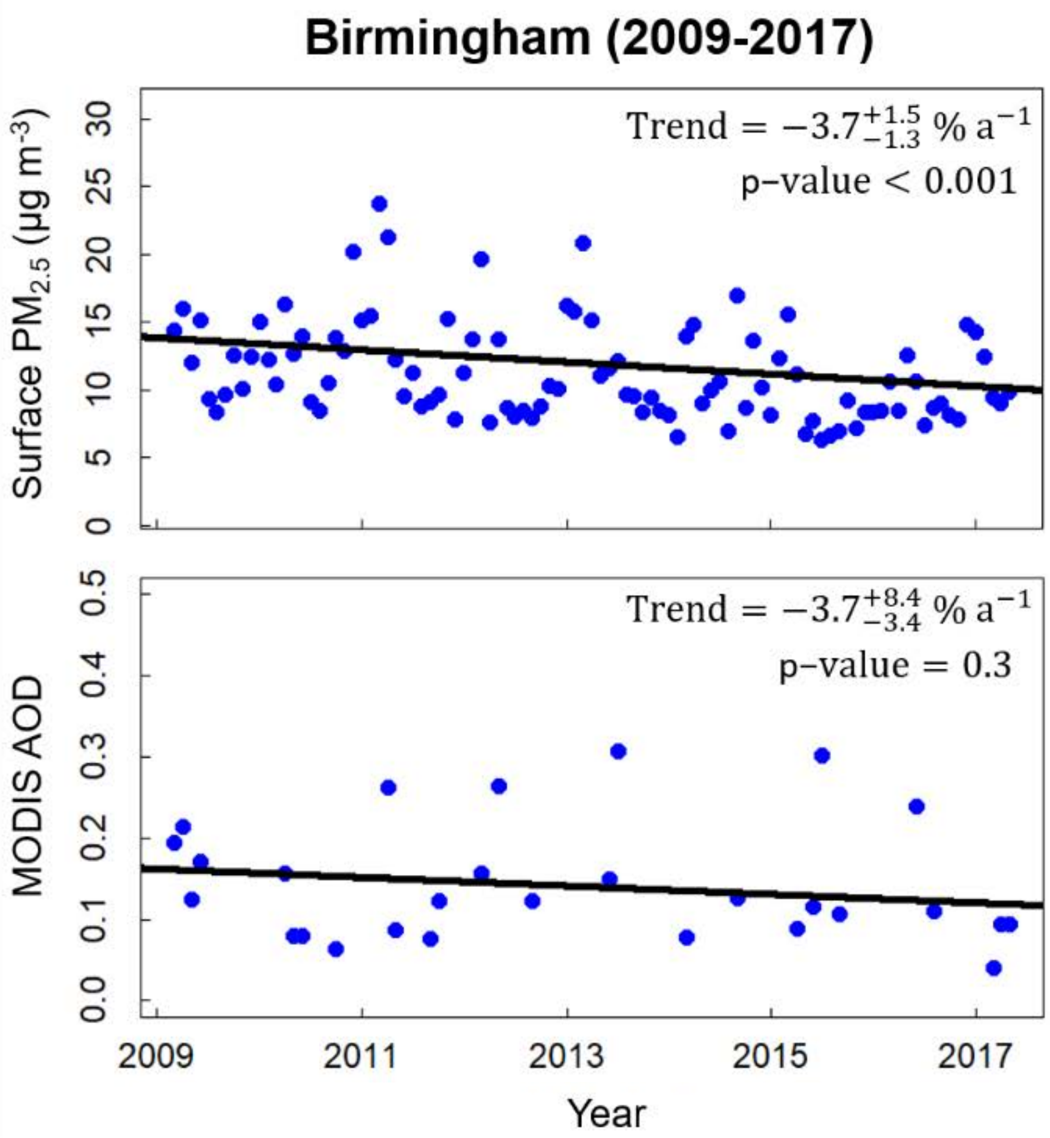
Temporal consistency observed between satellite and surface measurements of NO_2 and NH_3

[Vohra et al., 2021]

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

Satellite AOD versus surface $PM_{2.5}$ in Birmingham



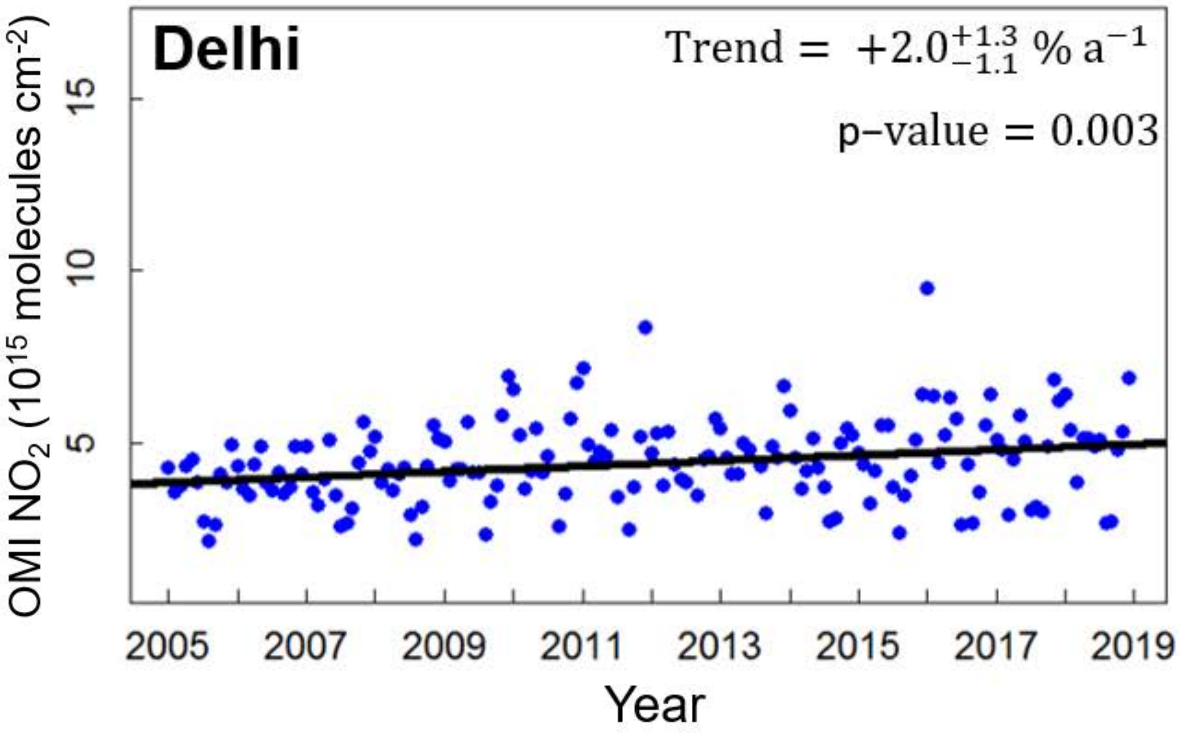


Similar results obtained for London

[Vohra et al., 2021]

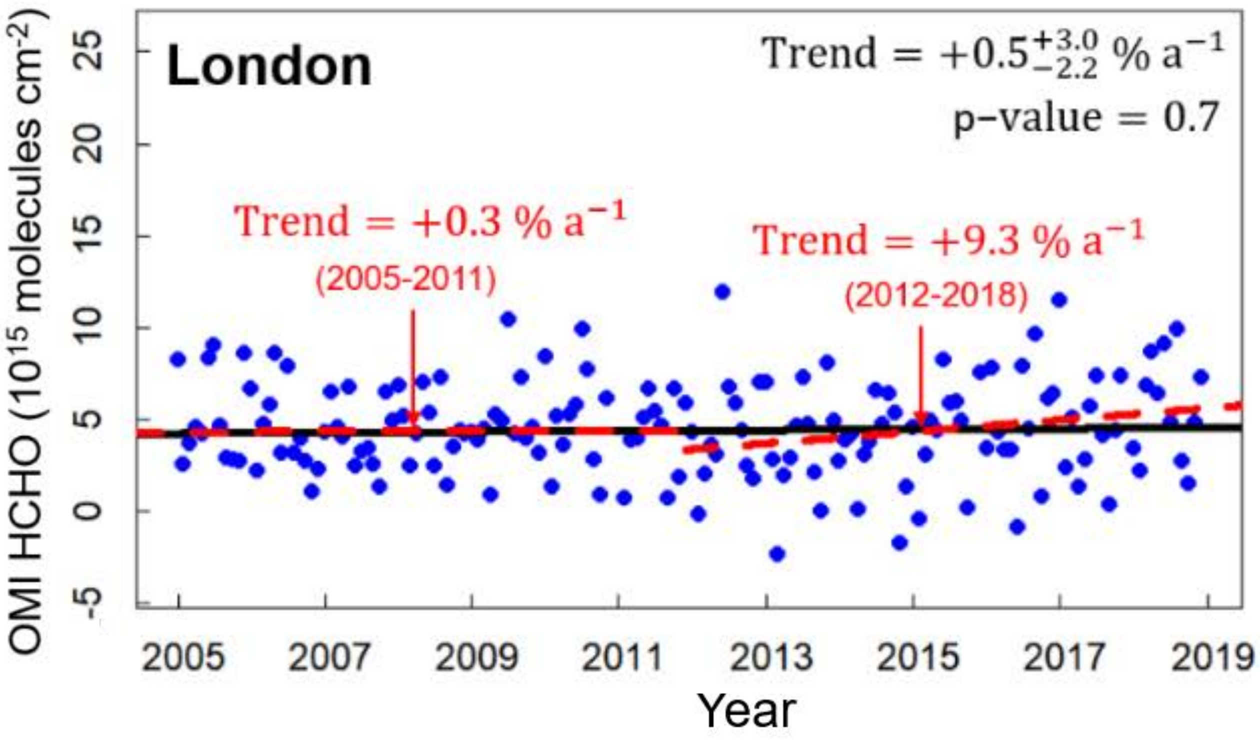
We apply trend analysis to long-term record of satellite observations

Trends in Delhi NO_2



No evidence of recent pollution control measures

Trends in London NMVOCs

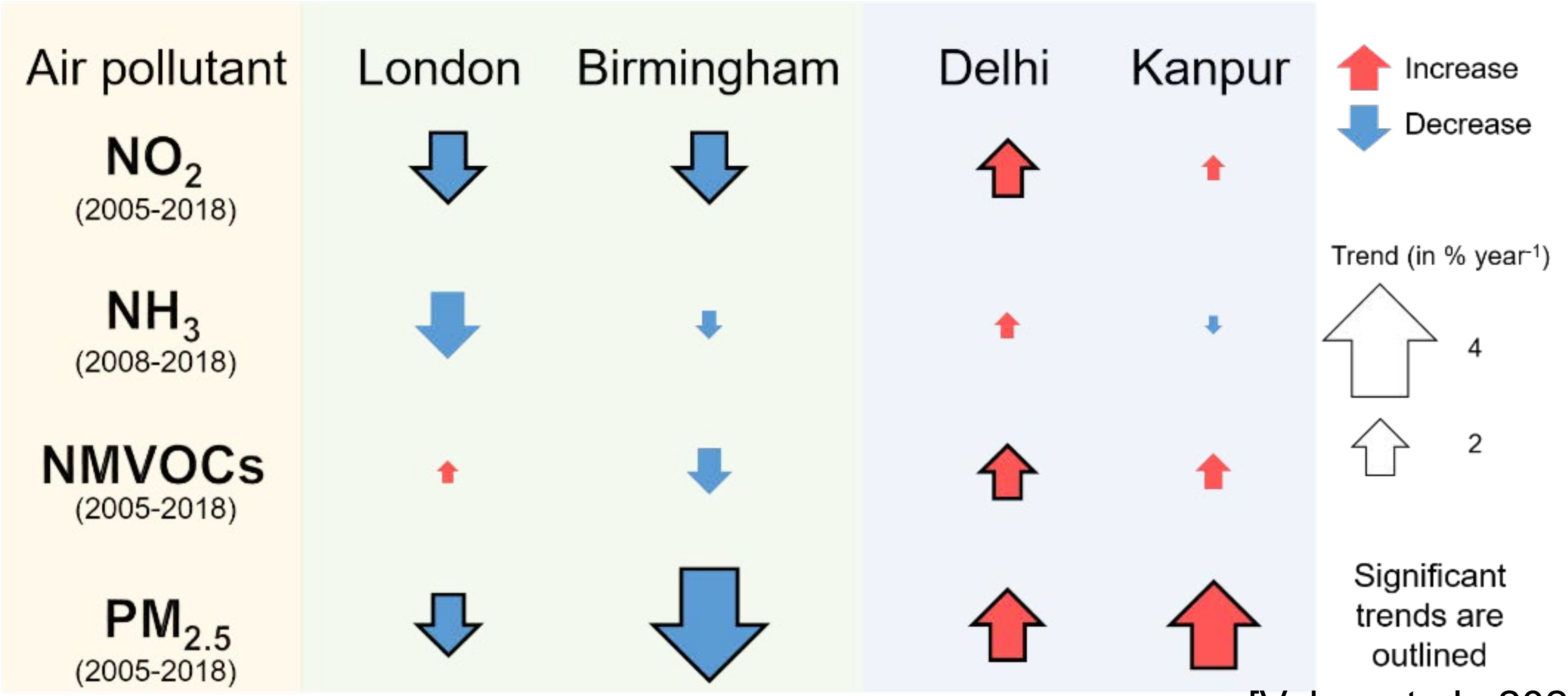


Recent dramatic increase in reactive NMVOCs

[Vohra et al., 2021]

Long-term air pollutant trends for cities in the UK and India

(Arrow colour and size indicate trend direction and magnitude respectively)



[Vohra et al., 2021]

Conclusion

- Satellite observations can be used to determine recent long-term trends in NO_2, NH_3, HCHO as a marker for reactive non-methane volatile organic compounds (NMVOCs) and AOD for $PM_{2.5}$
- Trends in all pollutants (except NH_3 in Kanpur) are positive in the Indian cities suggesting no improvements in air quality despite recent pollution control measures.
- Trends in all pollutants (with the exception of reactive NMVOCs in London) declined in cities in the UK likely due to successful control on vehicular emissions. **Reactive NMVOCs increased by more than 65 % in London** during 2012-2018 possibly due to increases in oxygenated VOCs from household products, the food and beverage industry and residential combustion.

Reference

K. Vohra, E. A. Marais, S. Suckra, L. Kramer, W. J. Bloss, R. Sahu, A. Gaur, S. N. Tripathi, M. Van Damme, L. Clarisse, P. F. Coheur, Long-term trends in air quality in major cities in the UK and India: A view from space, *Atmos. Chem. Phys.*, 21, 6275–6296, doi:10.5194/acp-21-6275-2021.

Severe health burden from fossil-fuel related $PM_{2.5}$

4.2 million deaths attributed to ambient $PM_{2.5}$ in 2015

[Cohen et al., 2017]

Dominant anthropogenic source;
Can be easily controlled

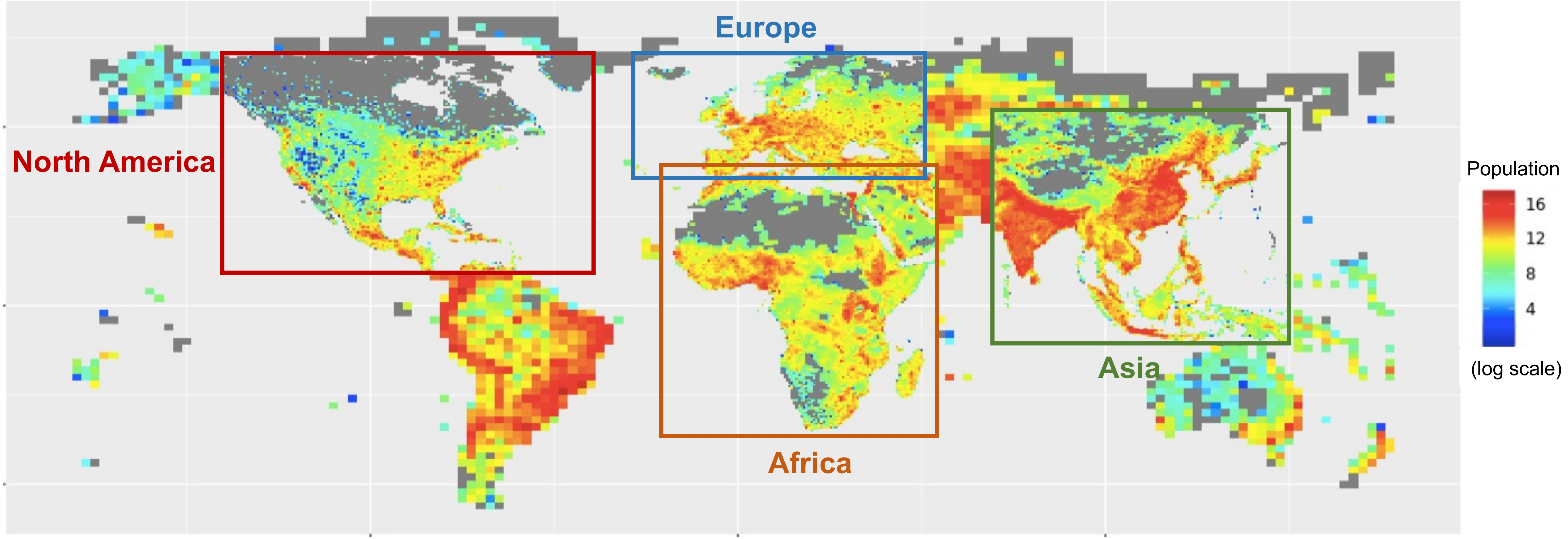
Particulate matter ($PM_{2.5}$)

- Fossil-fuels
- Dust ✗
- Wildfire smoke ✗
- Others ✗

In this study, we use a chemical transport model GEOS-Chem to estimate $PM_{2.5}$ contribution from fossil-fuel combustion

Model results of global and regional $PM_{2.5}$ for 2012

Population density (background) and model regions simulated (boxes)

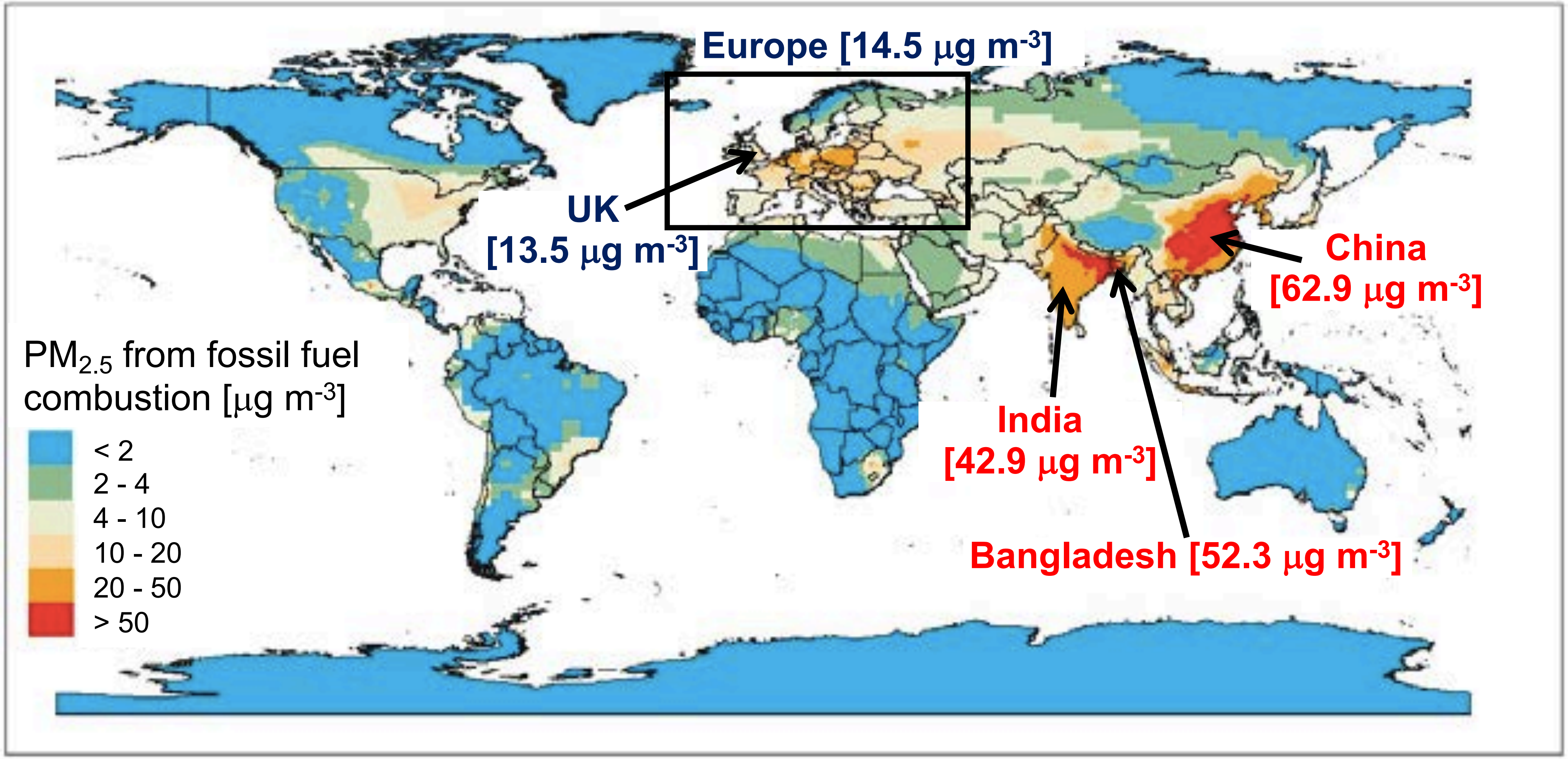


Global grid resolution : ~200-250 km
Regional grid resolution : ~50-67 km

Simulation 1 : All emissions
Simulation 2 : Fossil-fuel turned OFF

Model estimate of fossil fuel $PM_{2.5}$

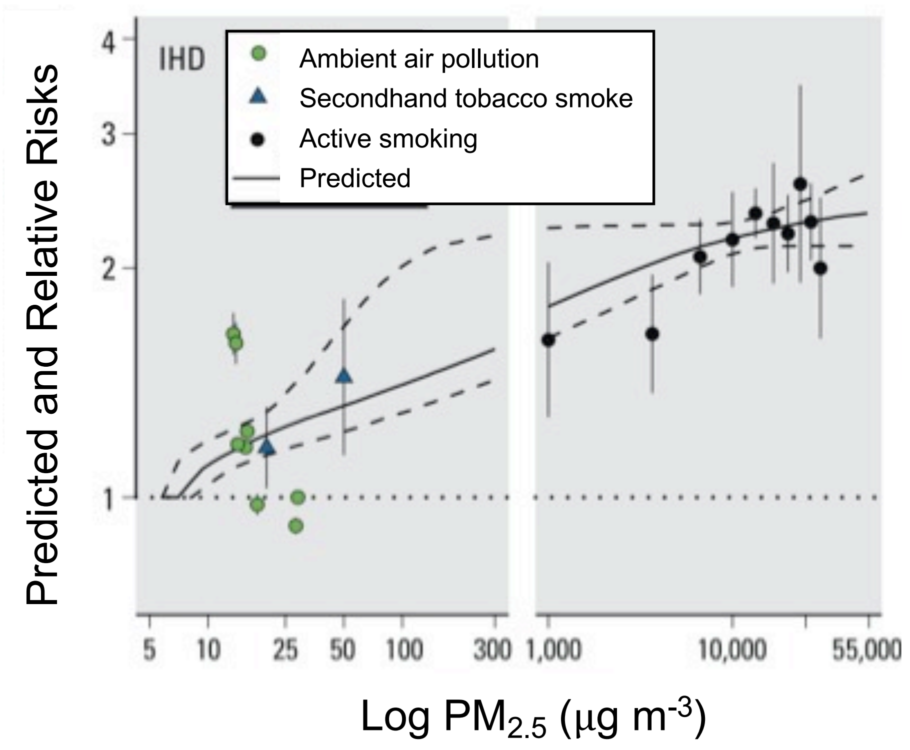
Difference between model simulations with and without fossil fuel $PM_{2.5}$



Hotspots are in China, Bangladesh, India, and central Europe

Standard and widely used risk assessment models

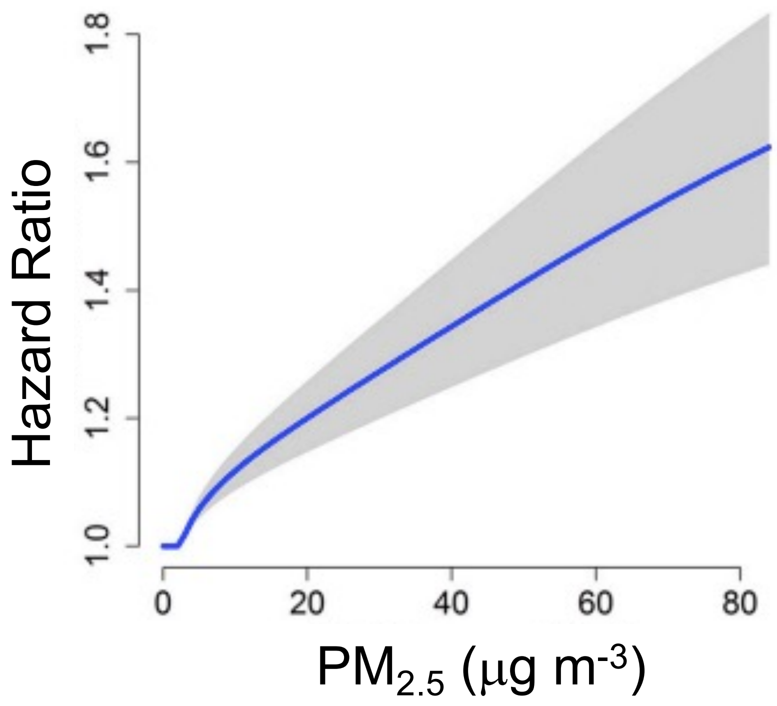
Integrated Exposure-Response (IER)



[Burnett et al., 2014]

Data includes active and passive smoking to address outdoor $PM_{2.5}$ > 40 μg m^{-3}

Global Exposure Mortality Model (GEMM)

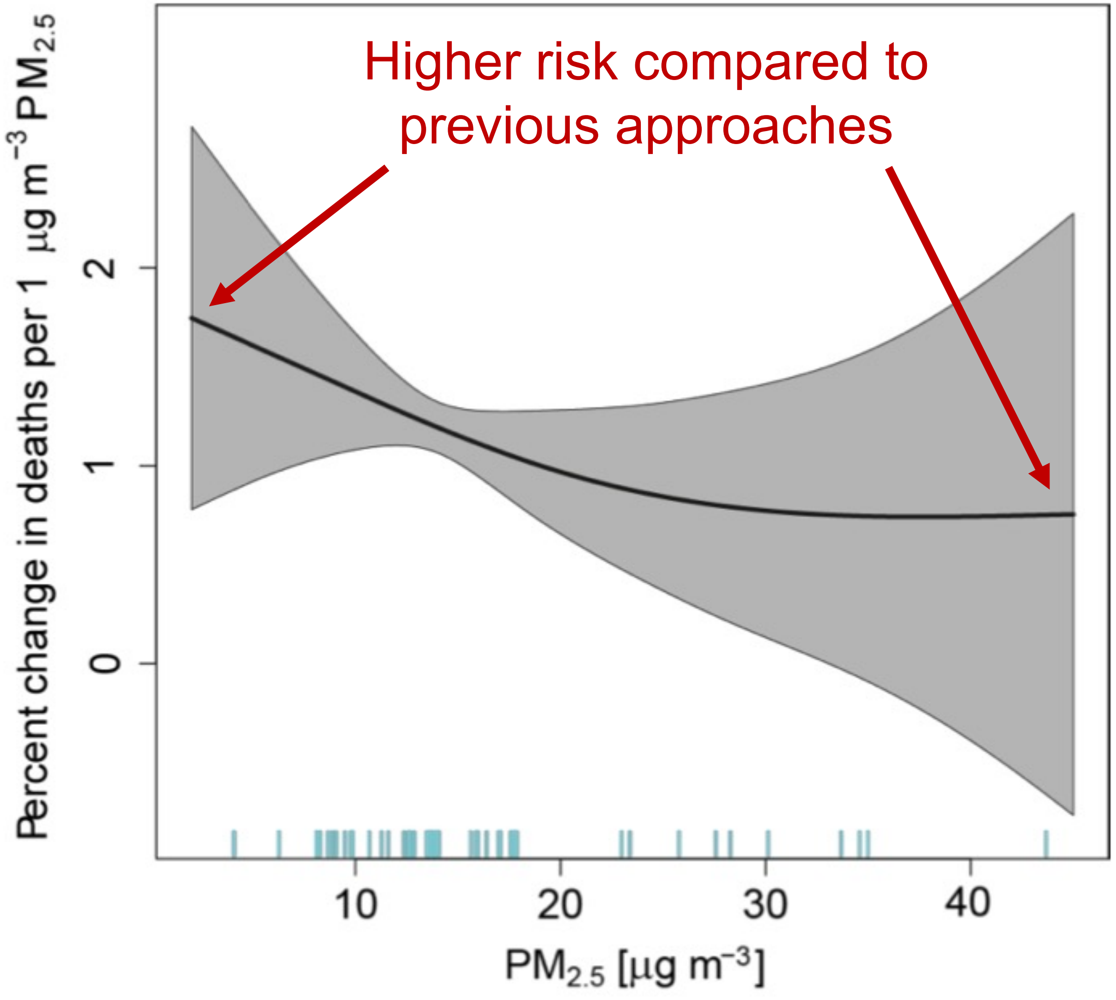


[Burnett et al., 2018]

41 cohort studies and model constrained using 4 parameters

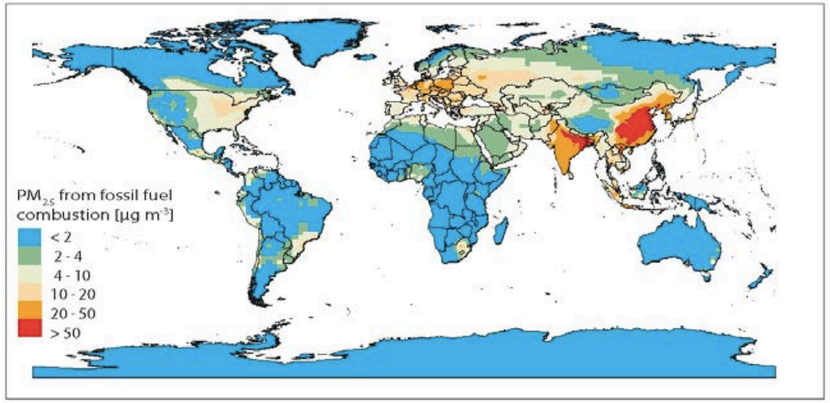
Updated risk assessment model used in our study

- Flexible shape of concentration-response function
- More cohort studies, and wider concentration and age range than previous approaches
- Includes death from all-causes

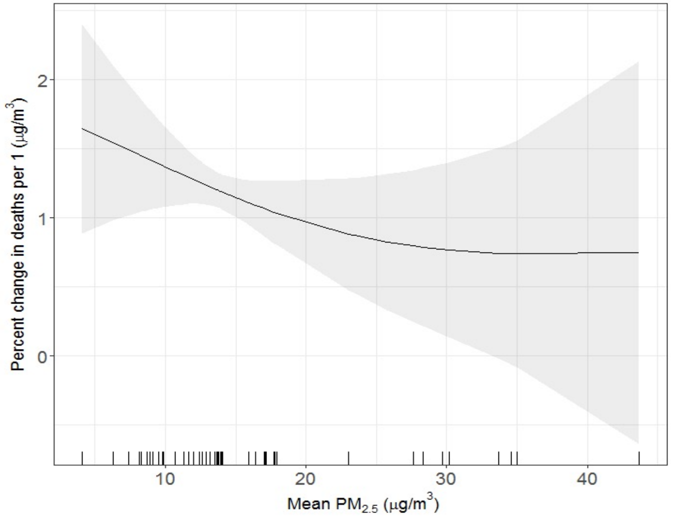


[Vodonos et al., 2018]

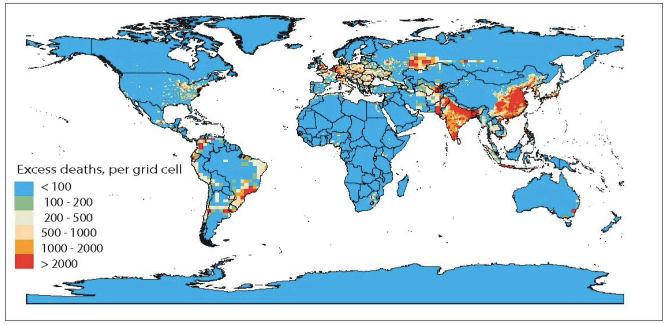
Methodology for health impact calculation



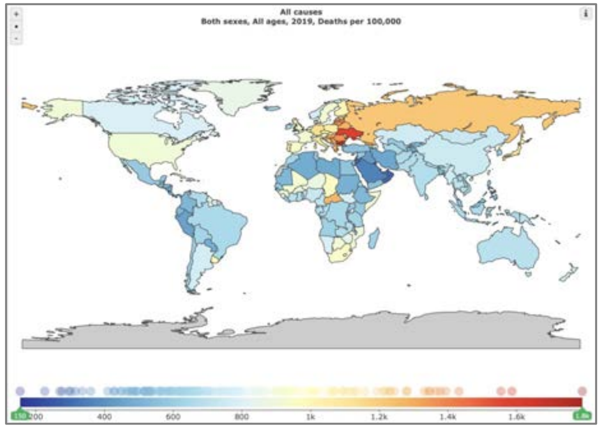
Fossil-fuel $PM_{2.5}$ from GEOS-Chem



Meta-analysis concentration-response function from cohort studies



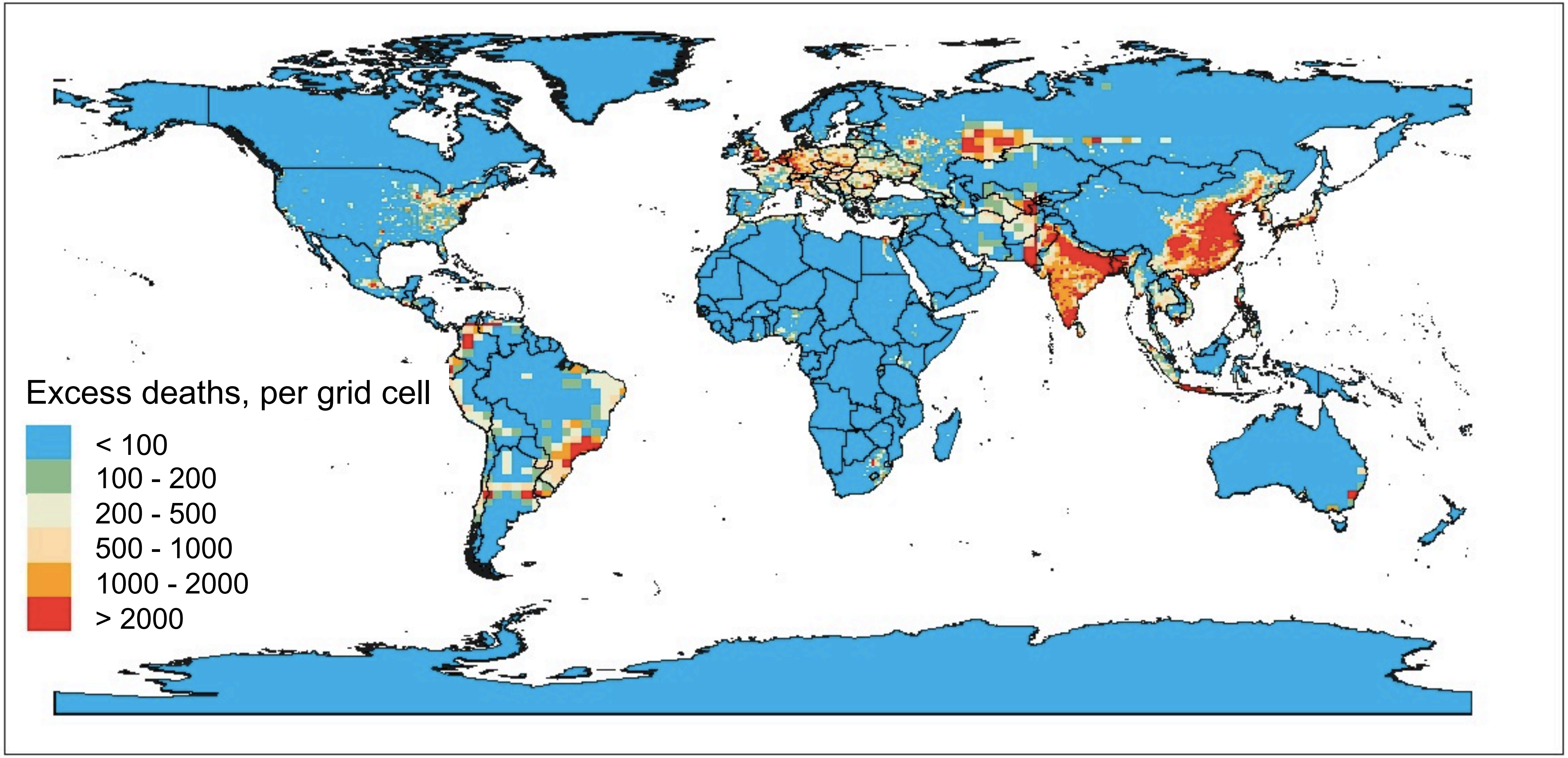
Global premature mortality estimates



Baseline mortality from Global Burden of Disease

We use the derived fossil-fuel $PM_{2.5}$ with baseline mortality in the meta-analysis concentration-response function to estimate global premature mortality

Estimated global premature mortality from fossil fuel combustion

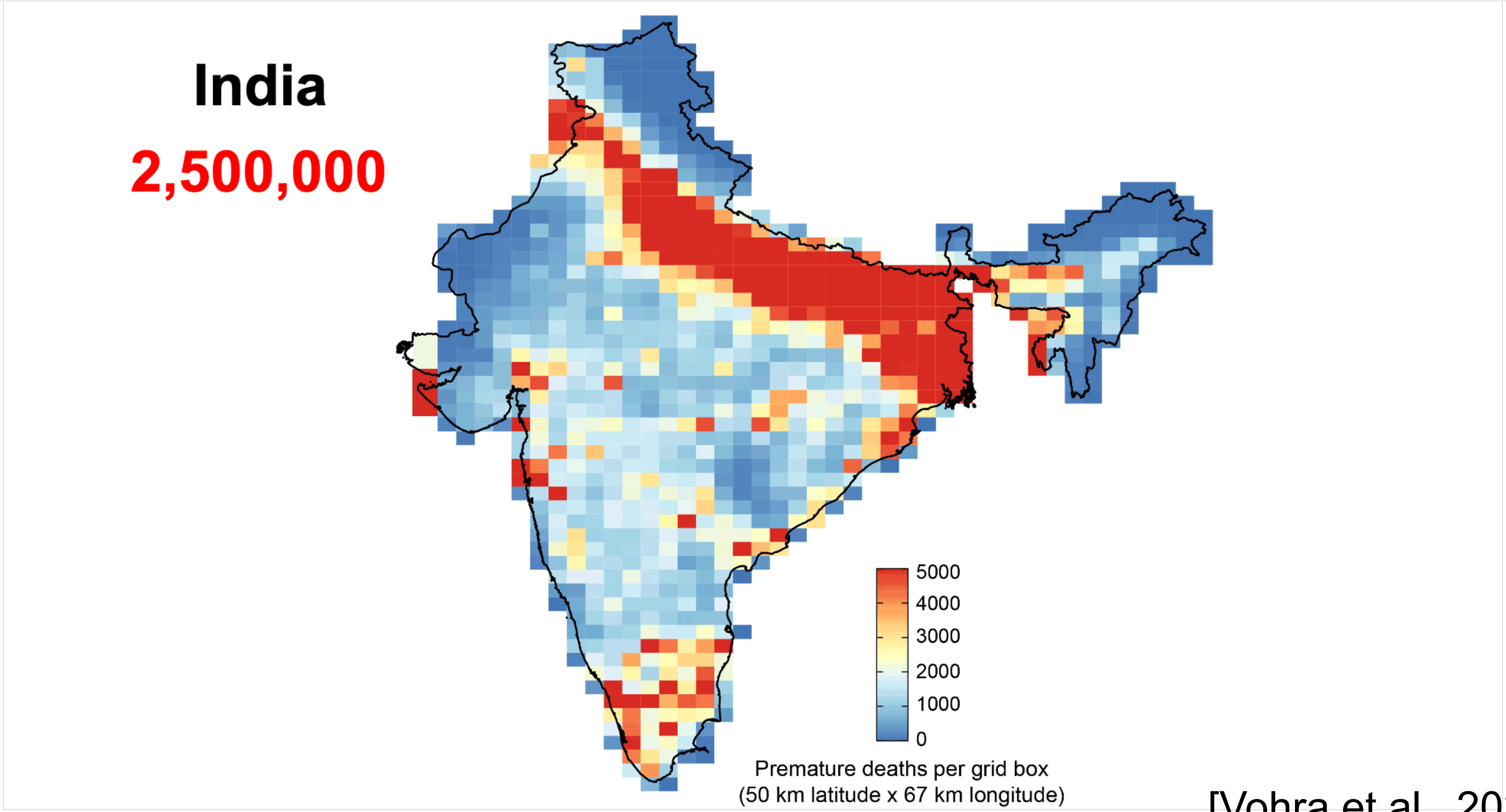


10.2 million premature deaths attributed to fossil-fuel $PM_{2.5}$ in 2012

[-47 million, 17 million]

[Vohra et al., 2021]

Regional premature mortality from fossil fuel combustion

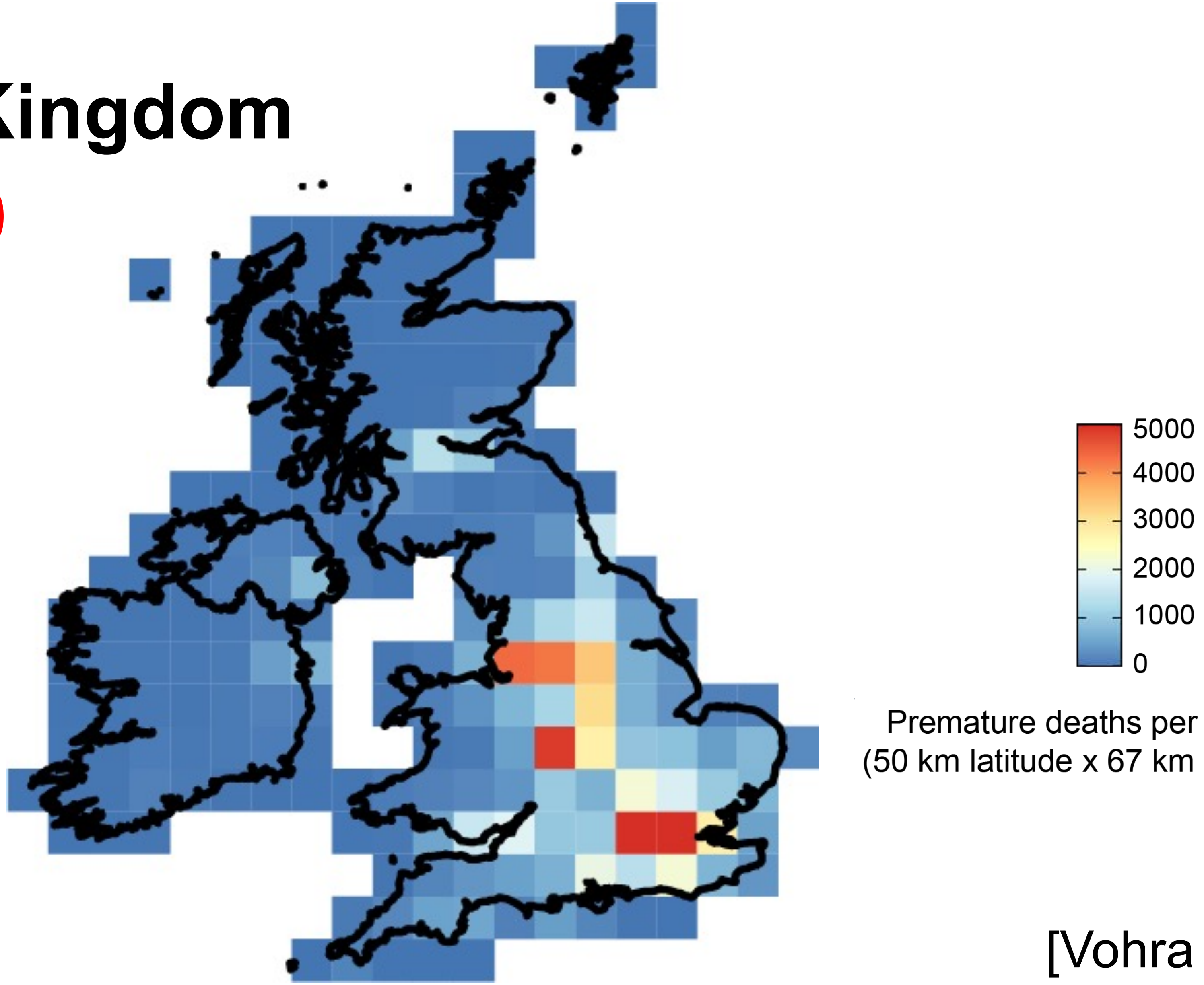


[Vohra et al., 2021]

Regional premature mortality from fossil fuel combustion

United Kingdom

99,000



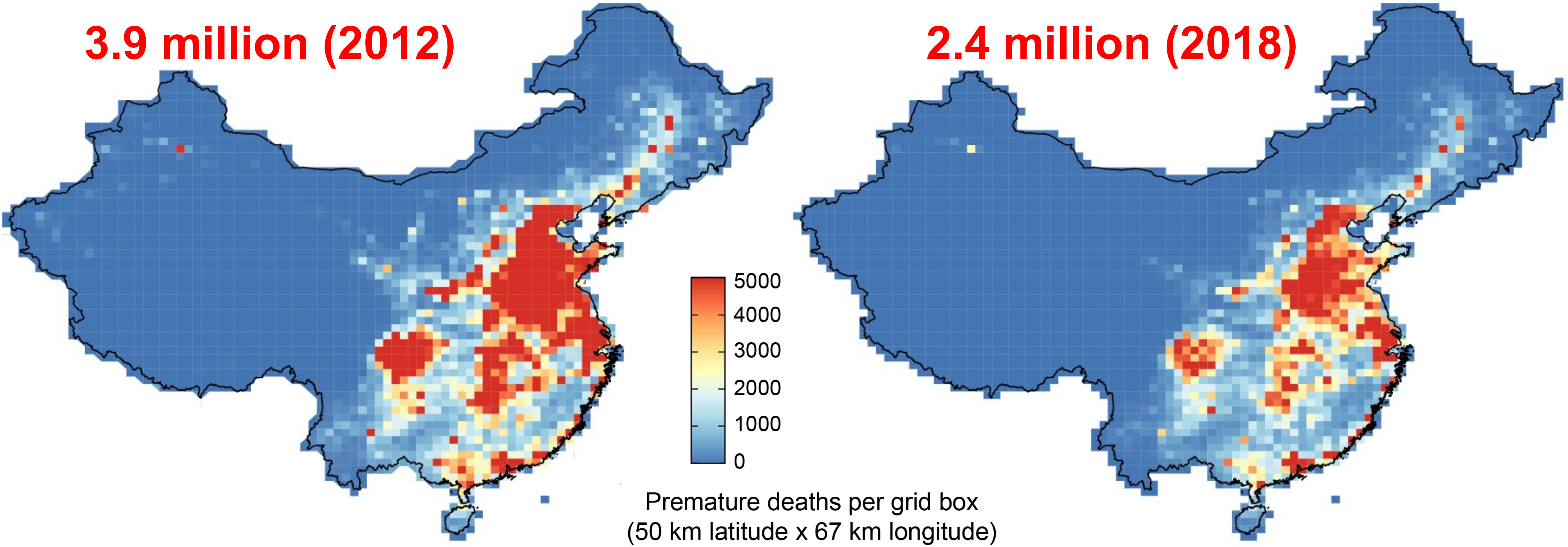
[Vohra et al., 2021]

Policies can help mitigate these premature deaths

China

3.9 million (2012)

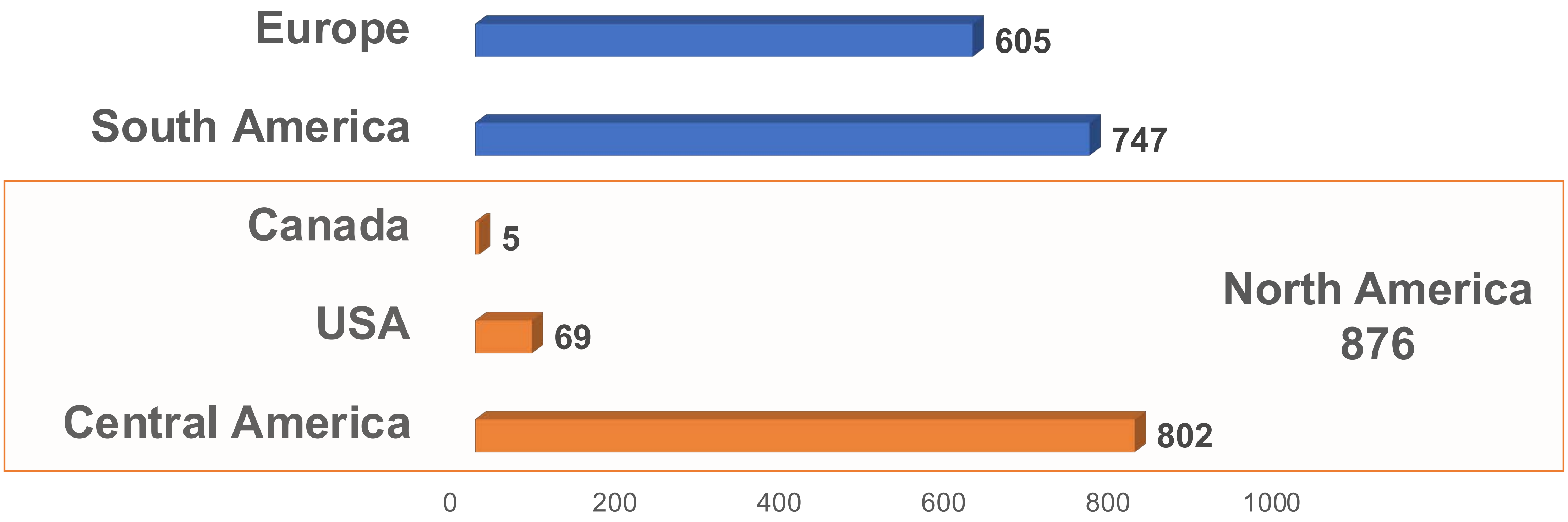
2.4 million (2018)



Dramatic reduction in $PM_{2.5}$ in China from 2012 to 2018 decreases premature deaths by 1.5 million

[Vohra et al., 2021]

Children are also affected by air pollution from fossil fuels



More than 2000 premature deaths from lower respiratory infection alone for children < 5 years old

[Vohra et al., 2021]

Implications of and response to our findings

We calculate global premature mortality that is much greater than previous estimates (updated risk assessment model, higher spatial resolution $PM_{2.5}$)

Greta Thunberg @GretaThunberg · Feb 9

"Air pollution caused by the burning of fossil fuels such as coal and oil was responsible for 8.7m deaths globally in 2018, a staggering one in five of all people who died that year"

'Invisible killer': fossil fuels caused 8.7m deaths globally in 2018, res...

Pollution from power plants, vehicles and other sources accounted for one in five of all deaths that year, more detailed analysis reveals

theguardian.com

https://www.theguardian.com/environment/2021/feb/09/fossil-fuels-pollution-deaths-research

Swell of media attention from leading news agencies and advocacy groups

Translated into **many languages** for audiences in France, Spain, India, Canada, China, Central and South America

Heightened immediate urgency to transition to cleaner and more sustainable energy sources

Conclusion

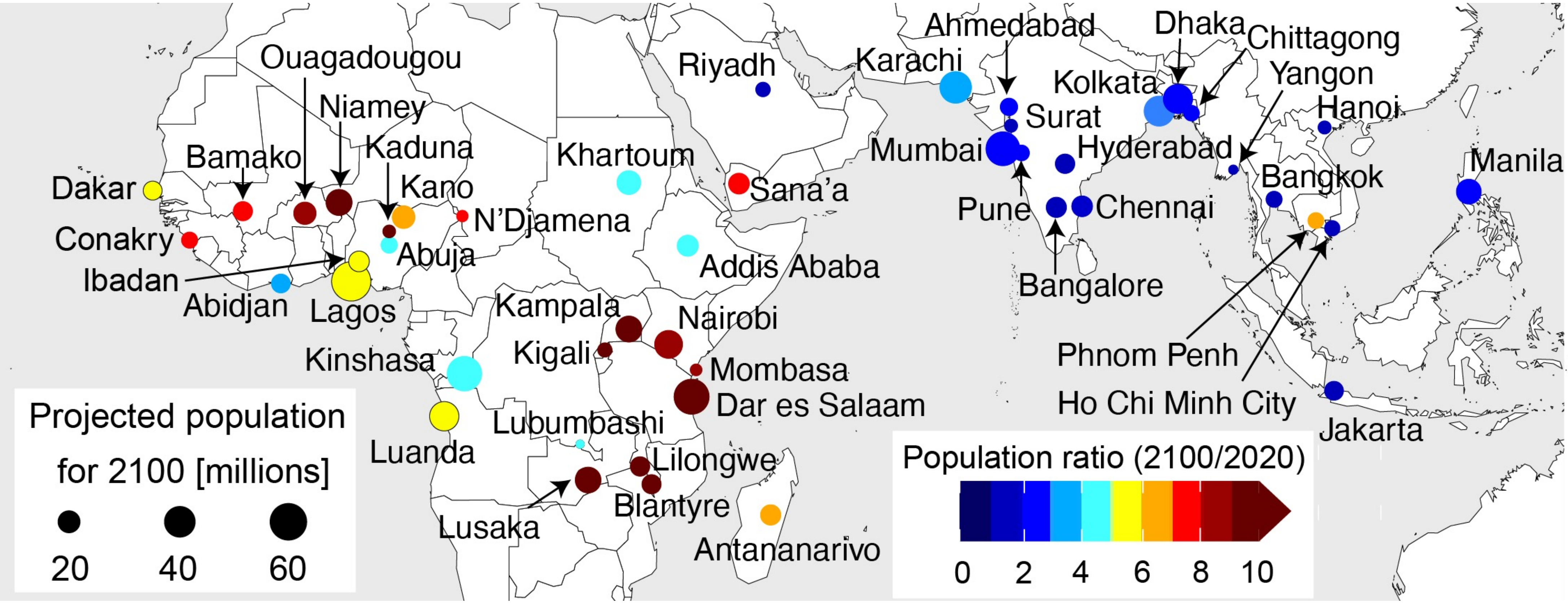
- Fossil-fuel related $PM_{2.5}$ pollution was responsible for **10.2 million adult premature deaths** in 2012 with more than 60 % of these deaths in China and India.
- Substantial reduction in fossil fuel use in China from 2012 to 2018 led to a 38 % decline in premature deaths from 3.9 million in 2012 to 2.4 million in 2018.
- Our premature mortality estimates are higher than previous studies (Cohen et al., 2017; Burnett et al., 2018) because we use an updated health risk assessment model and a finer spatial resolution chemical transport model.
- More than 2000 children in North America, South America and Europe were affected by lower respiratory infections as a result of exposure to $PM_{2.5}$ from combustion of fossil fuels.

Reference

K. Vohra, A. Vodonos, J. Schwartz, E. A. Marais, M. P. Sulprizio, L. J. Mickley, Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem, *Environ. Res.*, 195, 110754, doi:10.1016/j.envres.2021.110754, **ISI Web of Science Highly Cited Paper**.

Tropical cities are experiencing unprecedented growth

46 cities in tropical Asia and Africa will be megacities by 2100 [Hoornweg & Pope, 2017]



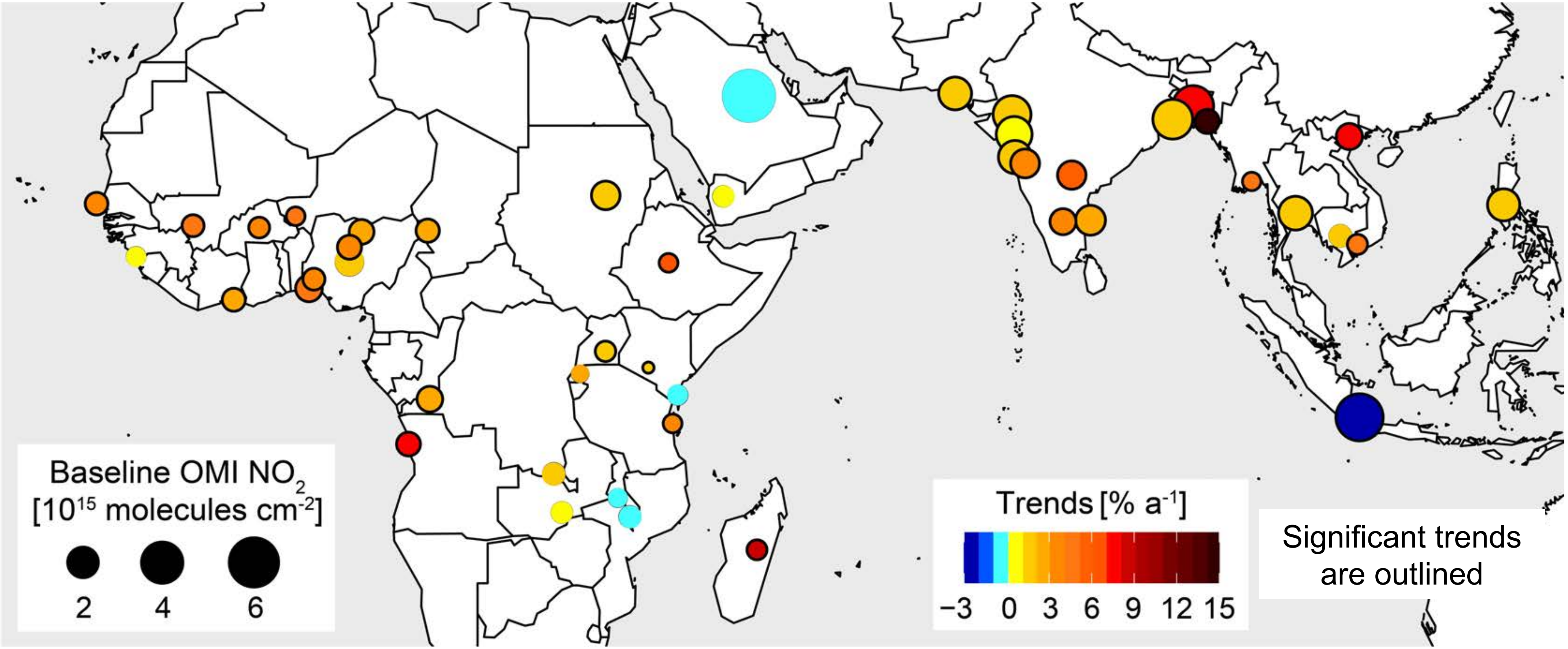
NO_2 | OMI | HCHO

IASI | NH_3

MODIS | AOD

Trends in NO_x in tropical future megacities in 2005-2018

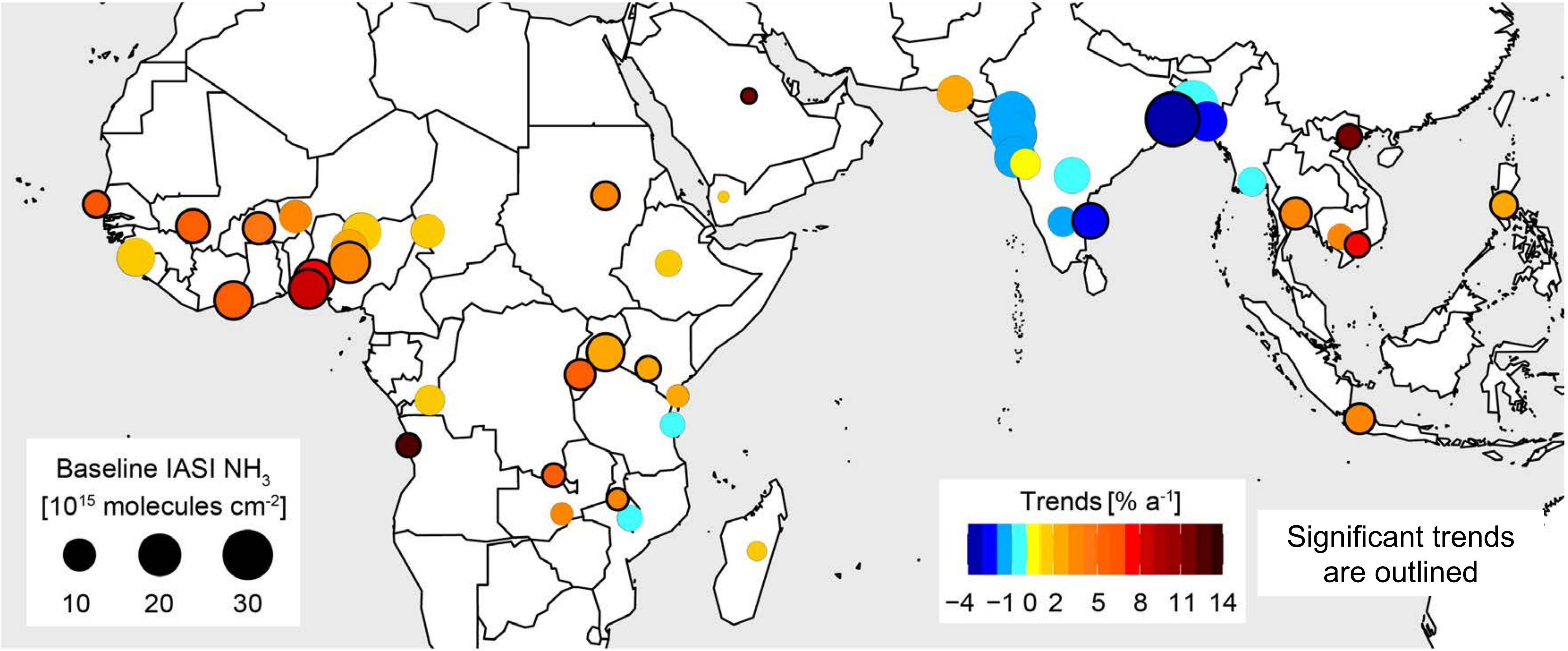
NO_2 increases in 41 cities by 0.1-14.1 % a^{-1}; leading to a gradual transition in ozone production regime from NO_x-sensitive to NO_x-saturated



[Vohra et al., *in review*]

Trends in NH_3 in tropical future megacities in 2008-2018

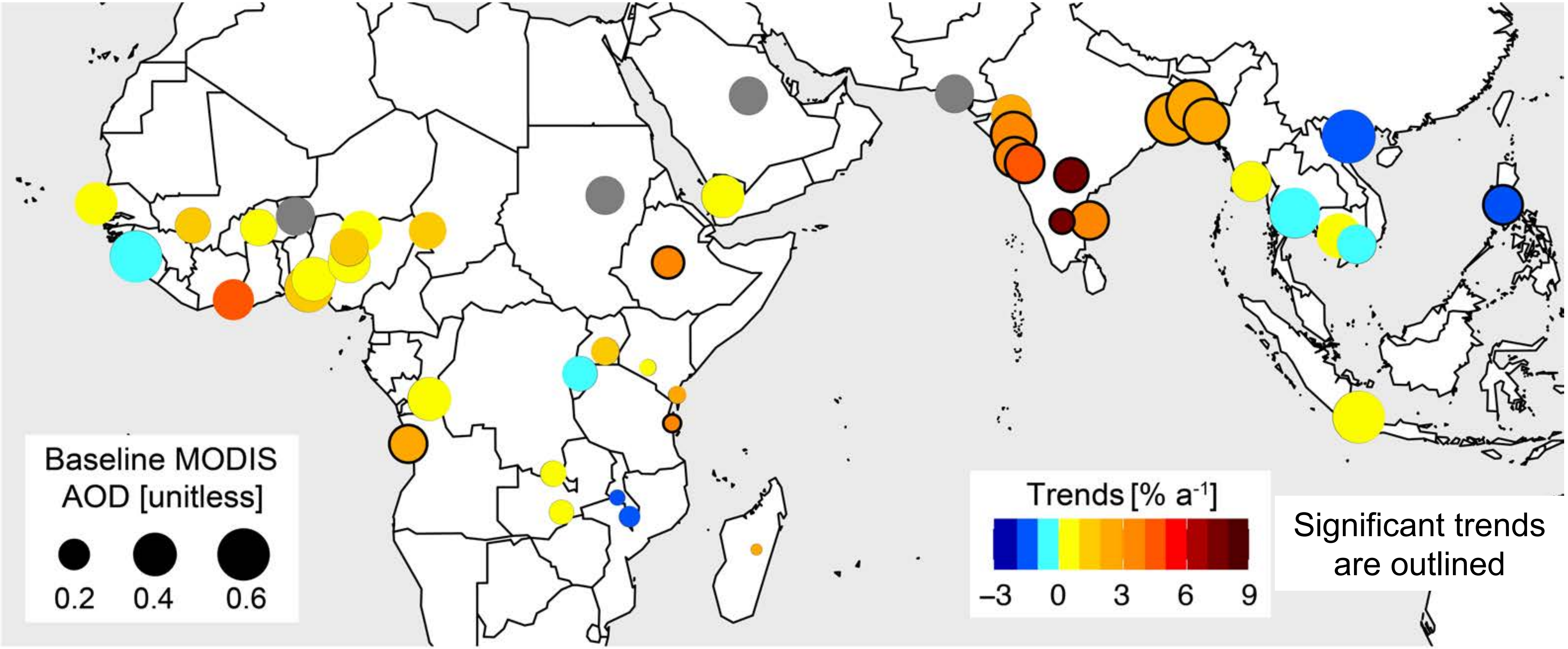
NH_3 increases in cities in all regions except the Indian subcontinent



[Vohra et al., *in review*]

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

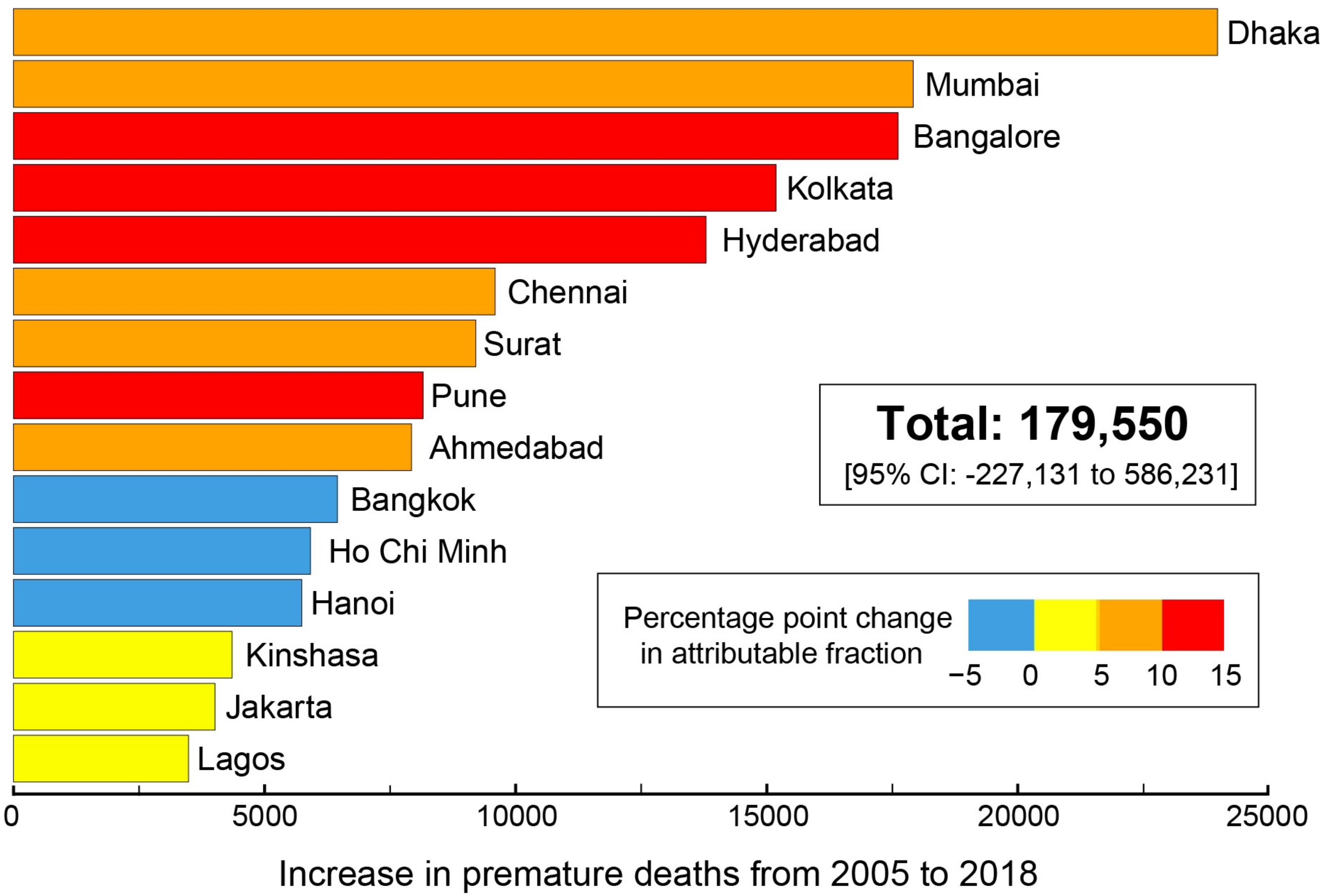
Large and significant increases of 3-8 % a^{-1} in $PM_{2.5}$ over Indian subcontinent



Dominant sources are many: secondary sources from NO_x, NH_3, NMVOCs, primary sources of windblown dust, crop and trash burning, residential and open fires

[Vohra et al., *in review*]

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

[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
- We estimate an increase in premature mortality by **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, Severe health burden in tropical future megacities from rapid rise in anthropogenic air pollution and population, in review, *Science Advances*.

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