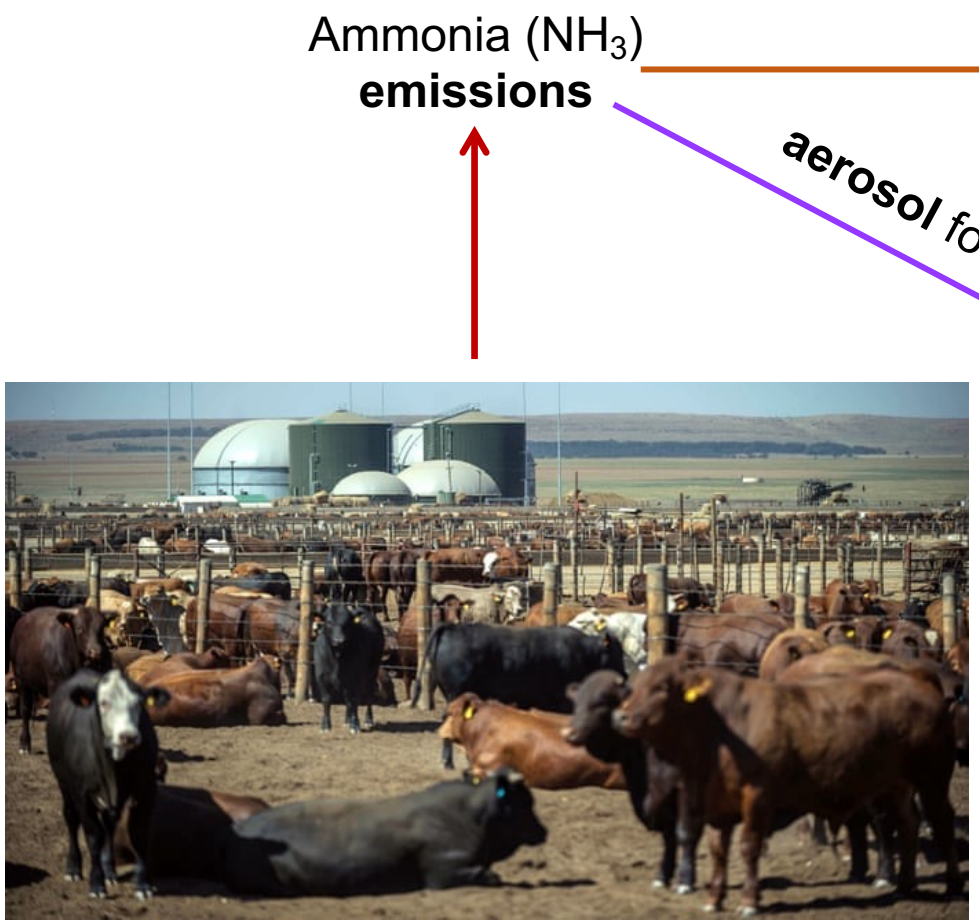
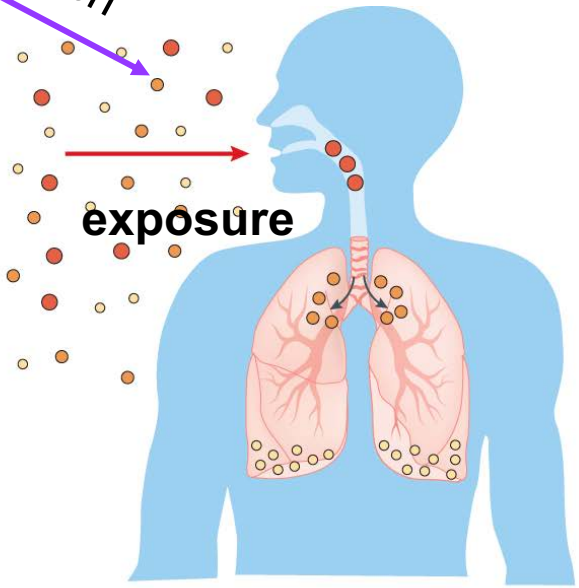
Agricultural emissions of ammonia are the most effective lever for addressing fine particulate matter pollution in the UK

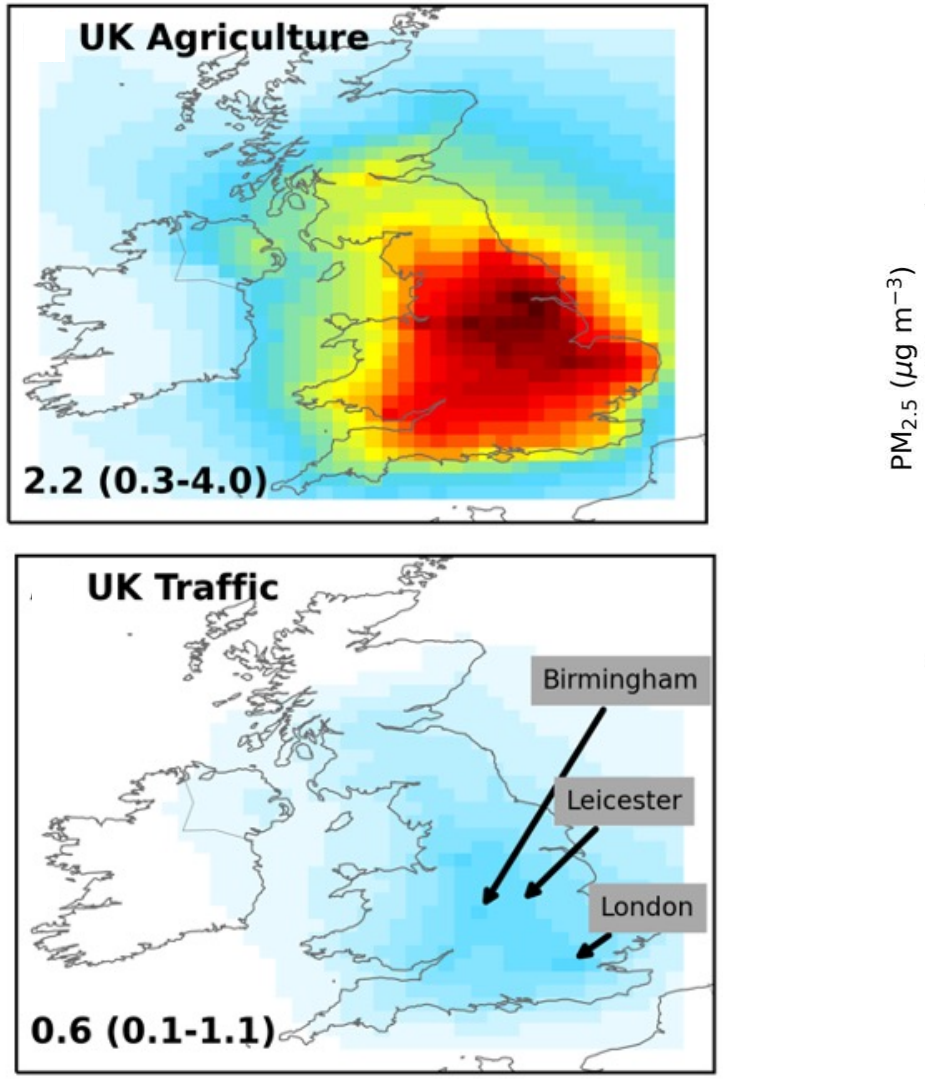




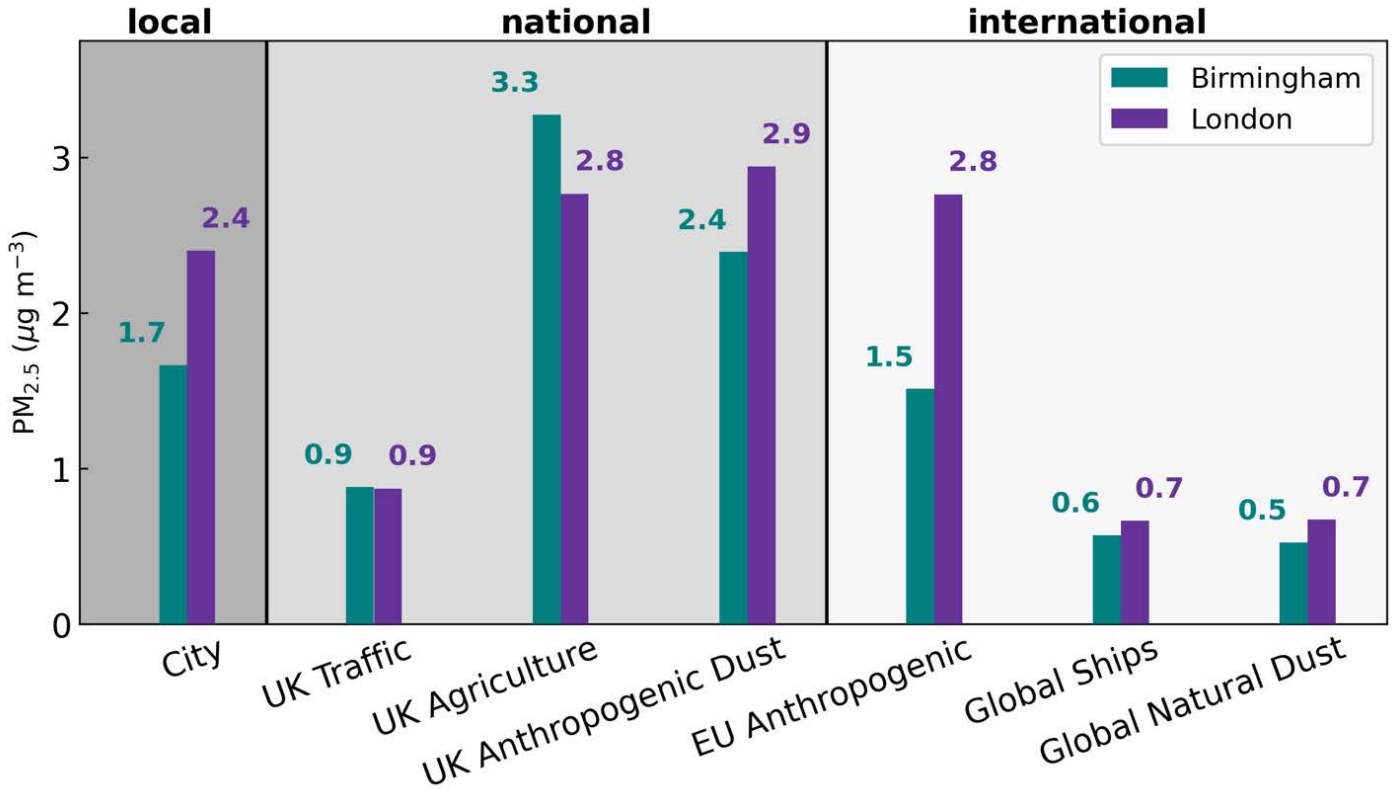
Eloise A. Marais with Jamie M. Kelly, Karn Vohra, Yifan Liu, Gongda Lu, Z. Klimont, J. White, and R. J. Leigh

Aerosol ammonium dominant component of $PM_{2.5}$ in UK cities

UK-wide $PM_{2.5}$ from select sources



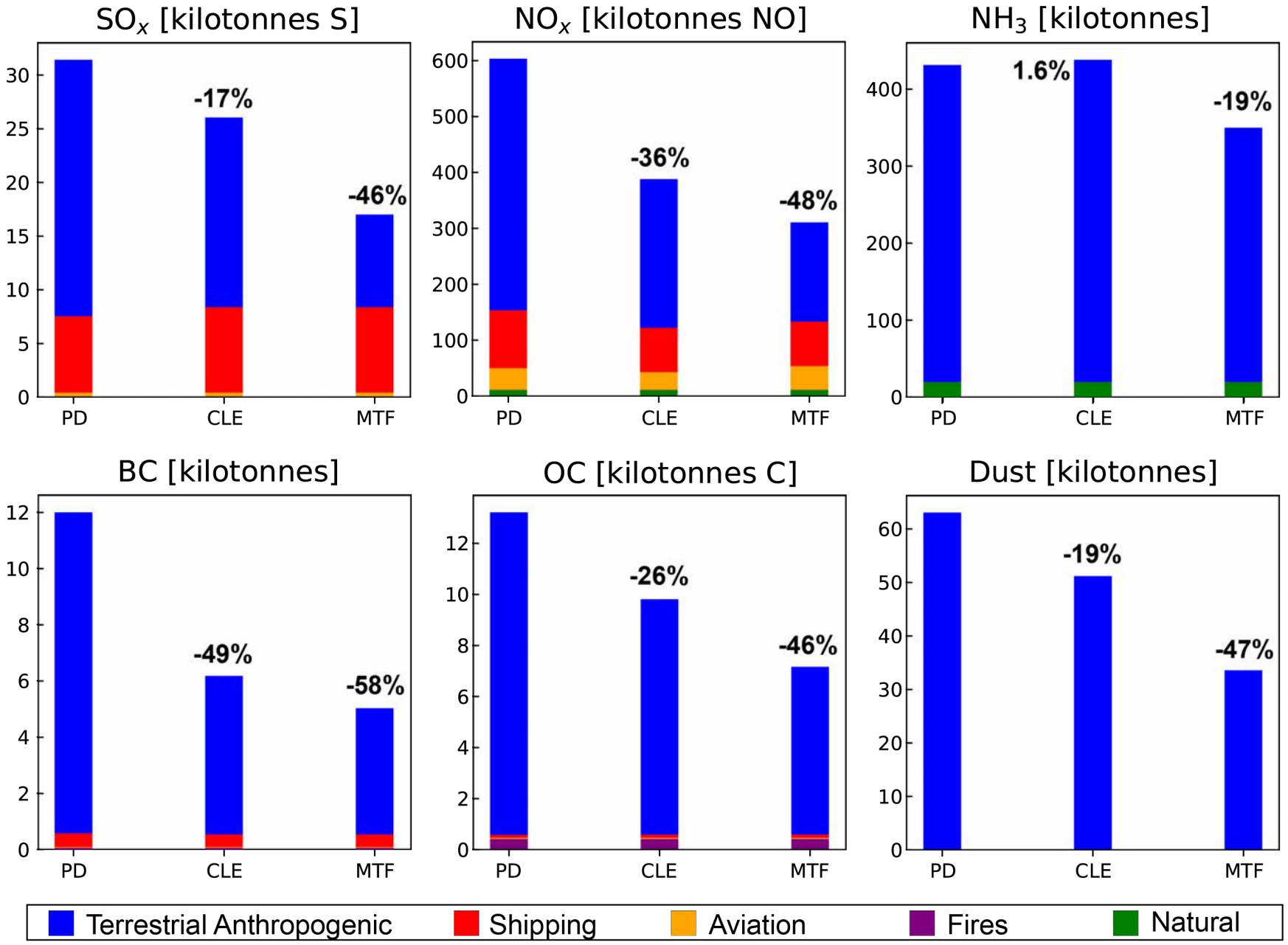
Sources of $PM_{2.5}$ in Birmingham and London



Agricultural NH_3 emissions largest contributor to $PM_{2.5}$ in all urban areas in the UK, except anomalously large London

[Kelly et al., 2022, in review]

$PM_{2.5}$ precursor emissions for implementation in GEOS-Chem



PD: present-day (2019)

Future (2030) emissions:

CLE: current legislation

MTF: max. technically feasible

NH_3 leading to aerosol ammonium (NH_4) increases under current legislation

Technically feasible solutions include low nitrogen feed, covered manure storage, improved manure spreading, air filters and scrubbers, and move from urea-based fertilizer

Model emissions impacts on $PM_{2.5}$ and nitrogen deposition

Emissions

Scales to match present day and future options

GEOS-Chem

3D Atmospheric Chemistry Transport Model

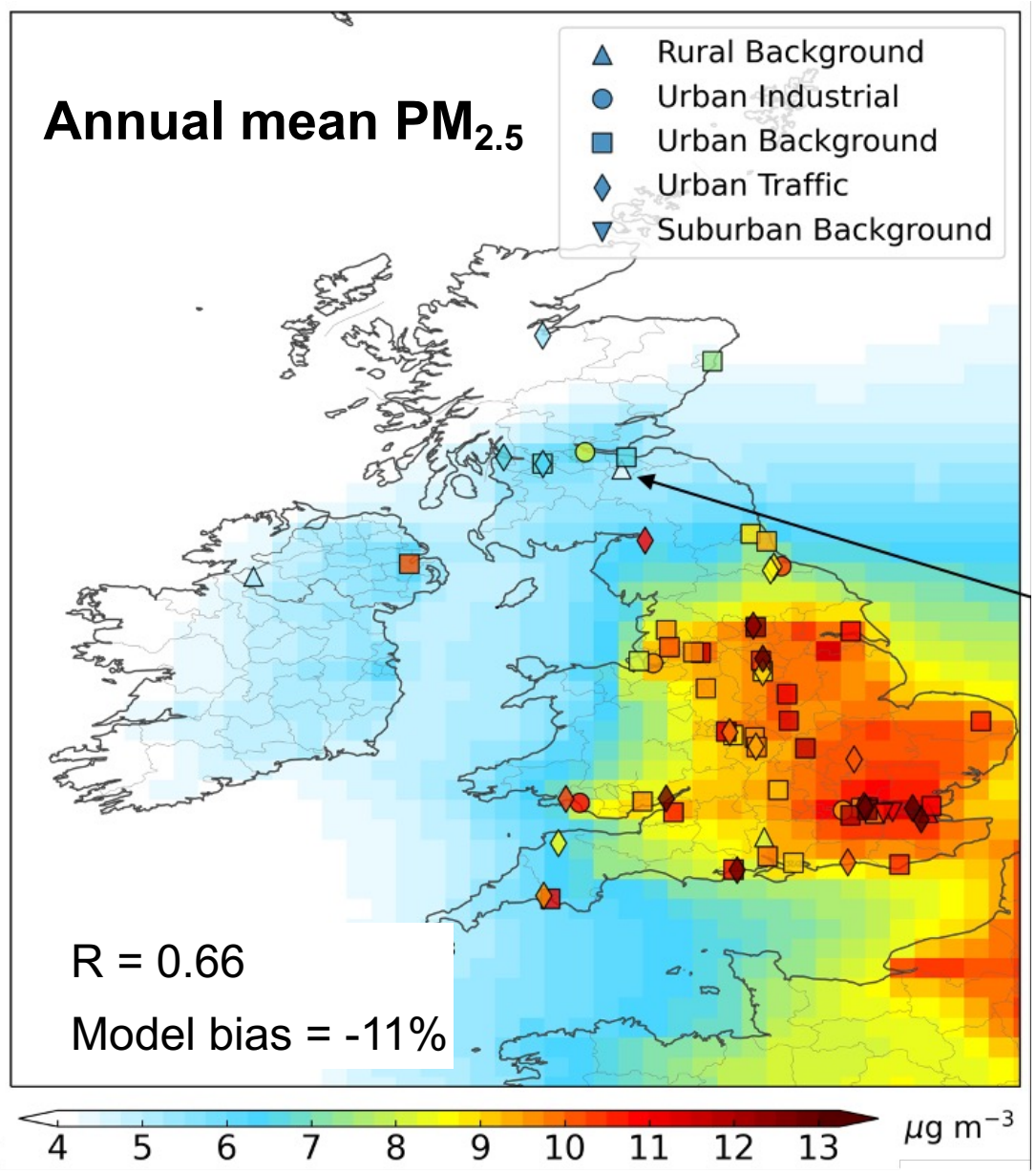
Chemistry, transport, sinks

NASA GEOS-FP Meteorology

Surface $PM_{2.5}$

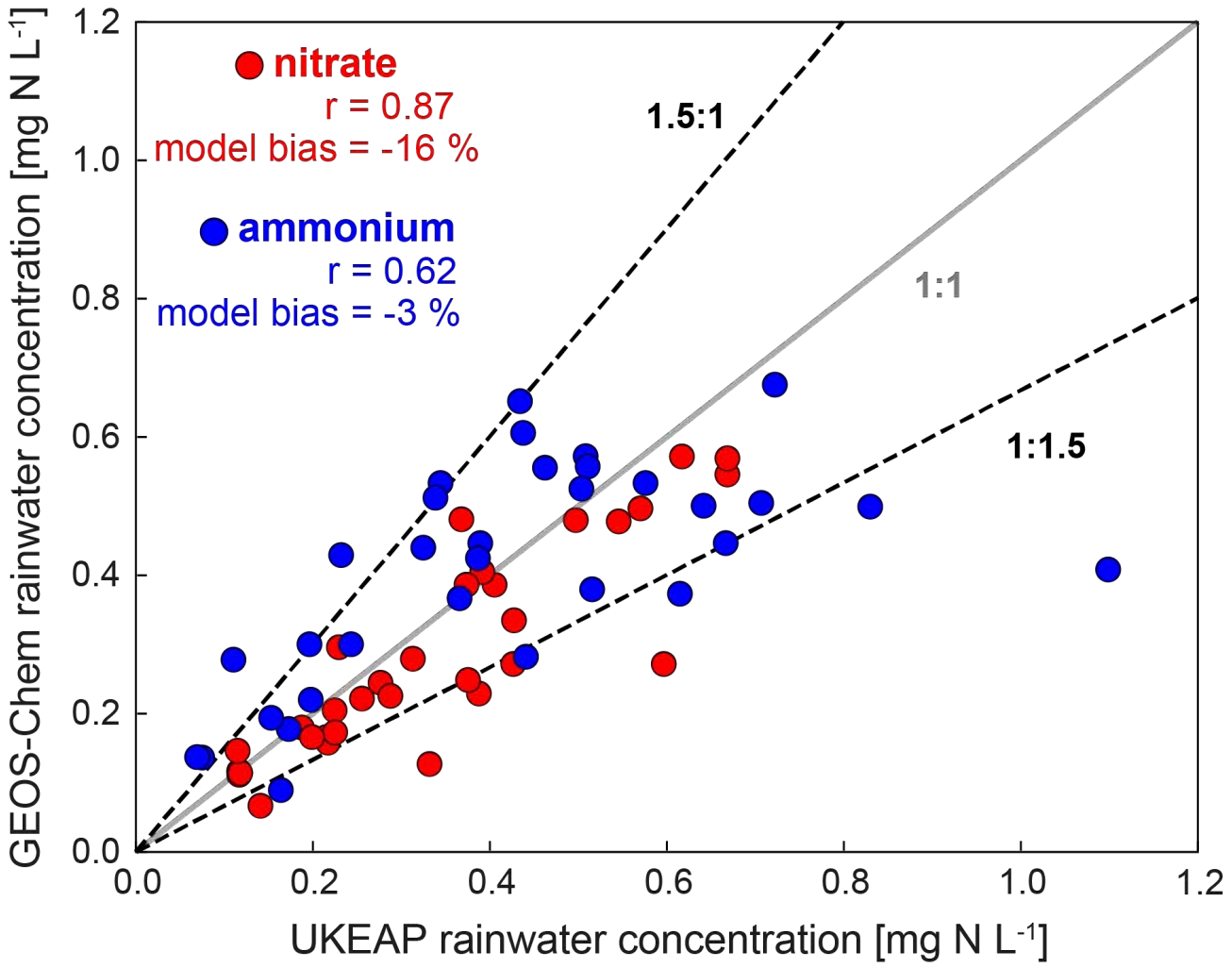
Nitrogen wet and dry deposition

Assessment of modelled $PM_{2.5}$ and deposition



[Kelly et al., 2022, in review]

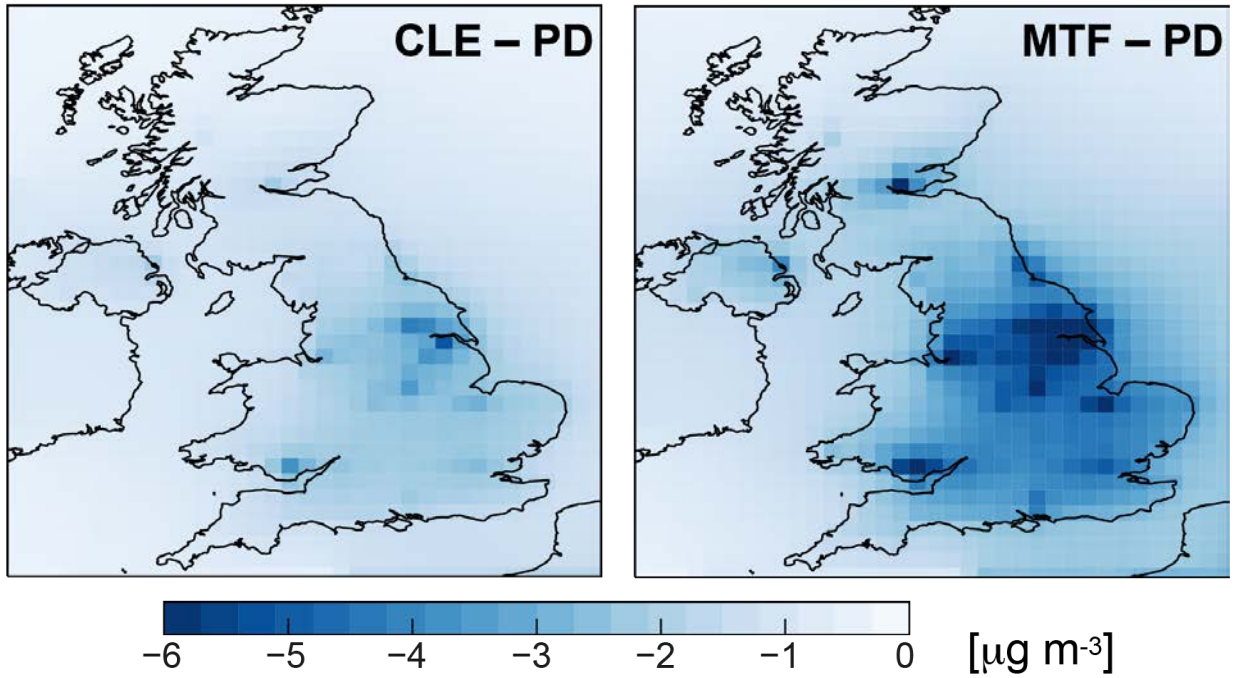
Rainwater nitrate and ammonium



Includes correction to model (GEOS-FP) underestimate in rainwater volume

Air Quality Impacts of Future Mitigation Measures

Change in $PM_{2.5}$ relative to the present-day due to emission controls



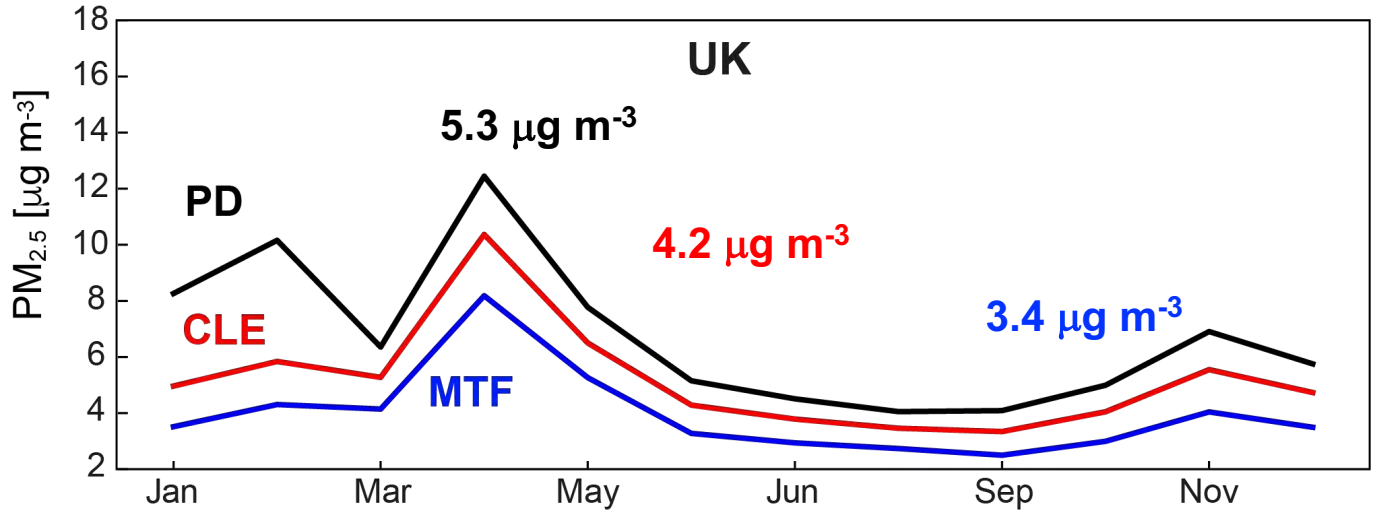
Average decline in $PM_{2.5}$ in the UK of 21% with current legislation and 36% with maximum technically feasible options

Decline greatest over densely populated urban areas and North Yorkshire (coal-fired power plants)

Percent UK grids above the updated WHO guideline (5 μg m^{-3}) decreases from 48% in PD to 32% for CLE, and 2% for MTF

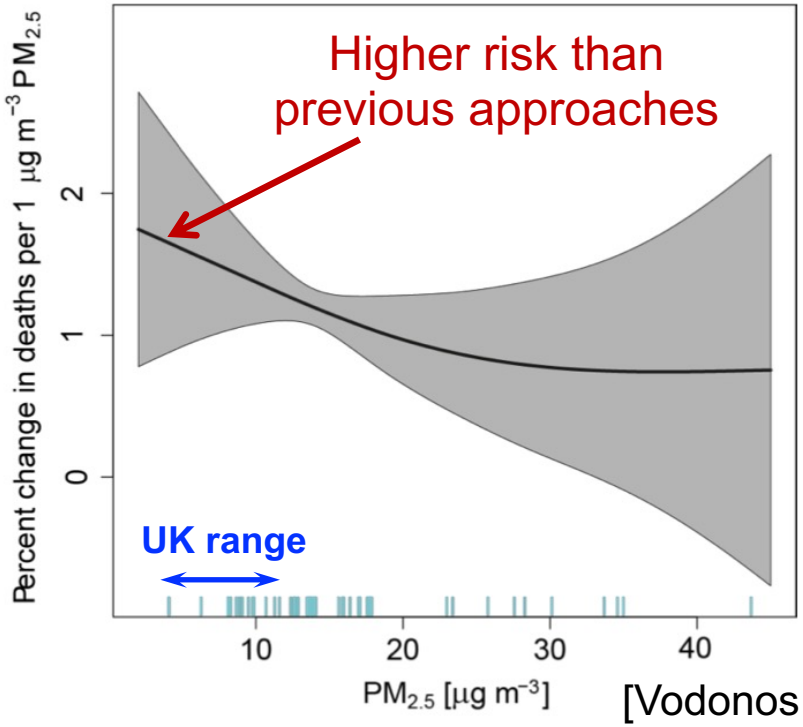
Similar decline in $PM_{2.5}$ in all months, except Jan-Feb.

Reduces vulnerability to interannual variability in meteorology (dry, stable conditions)



Public Health Impacts of Future Mitigation Measures

Health risk curve used in this study

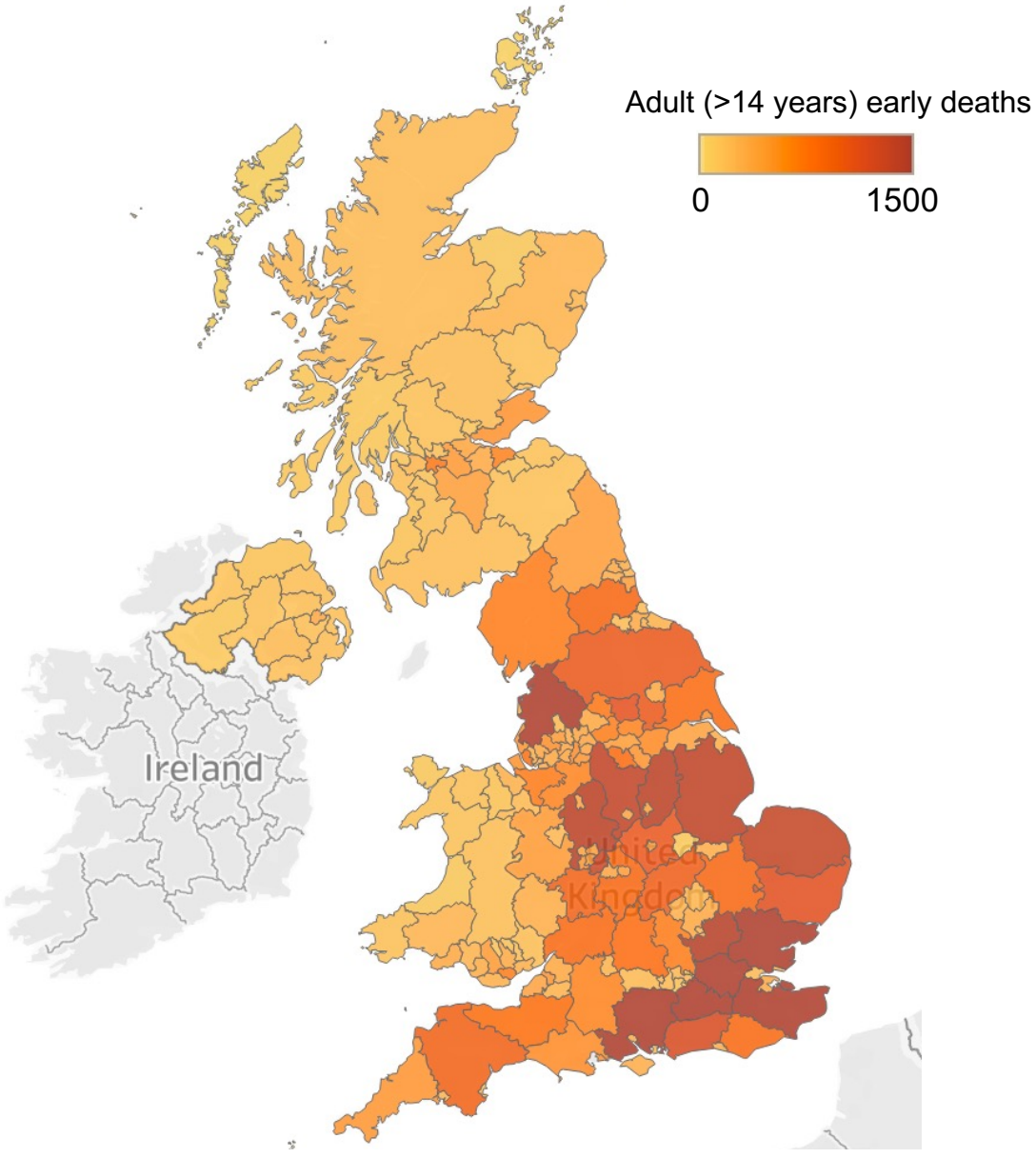


[Vodonos et al., 2018]

Baseline mortality of ~66,000 deaths in 2019. Previous estimate of ~29,000 for the UK by Public Health England (PHE) for 2010.

Avoided deaths of ~11,000 for current legislation and of ~22,000 if adopt maximum technically feasible solutions

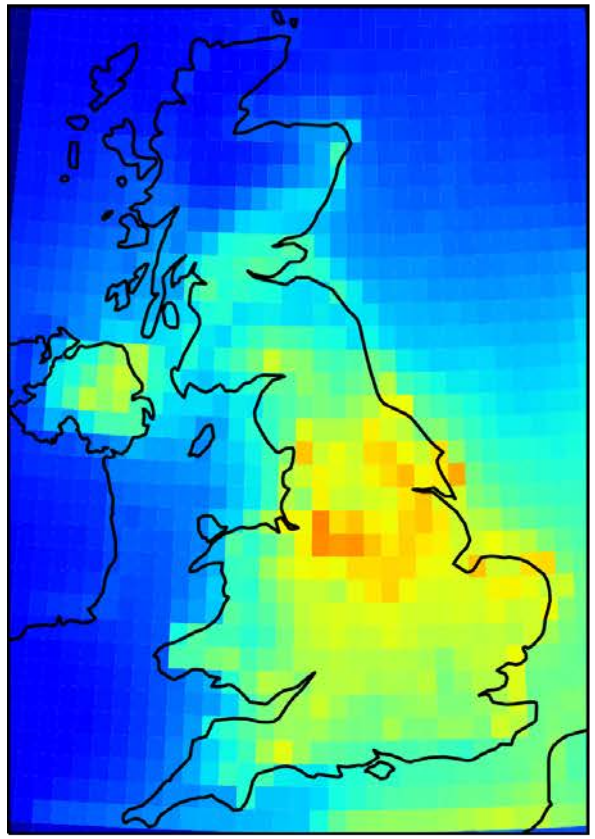
Early deaths from $PM_{2.5}$ exposure in 2019



Ecosystem Impacts of Future Mitigation Measures

Reduced (ammonium) and oxidized (nitrate) nitrogen deposition today and likely in the future

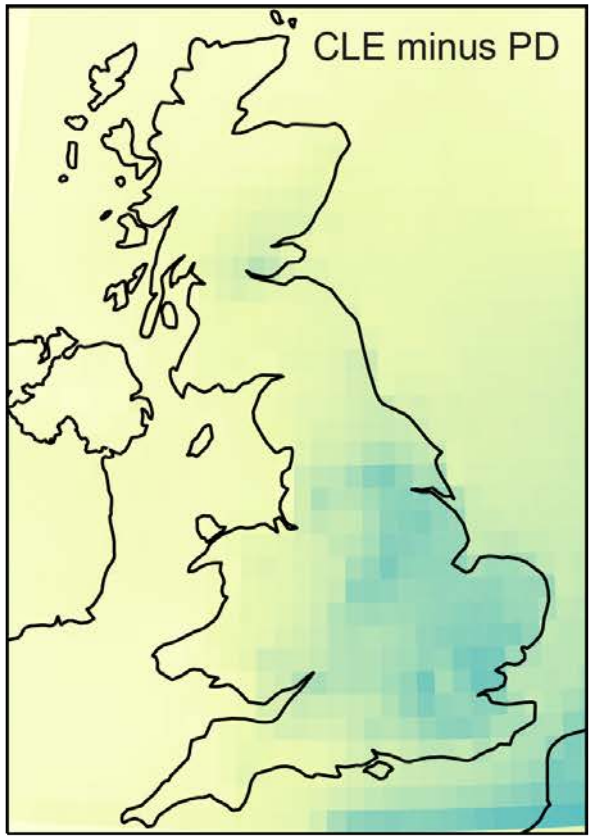
Total N deposition in 2019



0 4 8 12 16 [kg N ha^{-1}]

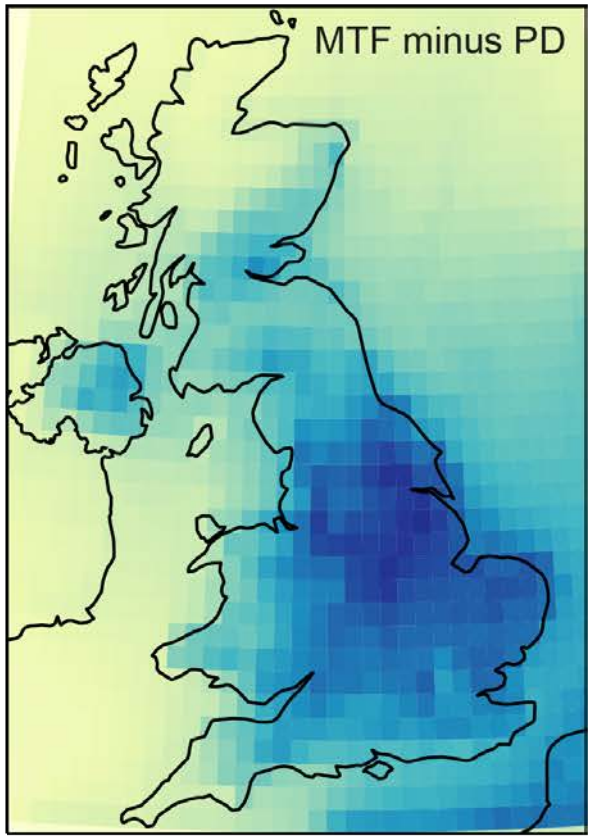
Total: **429 Gg N**
Ammonium (NH_x): **252 Gg**
Nitrate (NIT): **177 Gg**

Decline in total annual N deposition due to emission controls



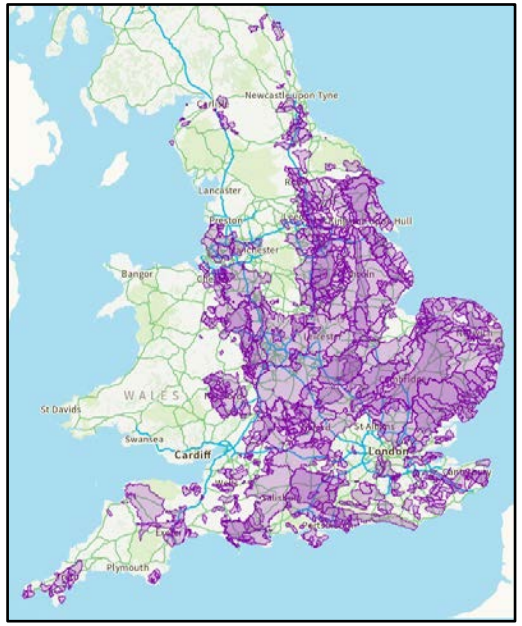
−4 −3 −2 −1 0 [kg N ha^{-1}]

48 Gg decrease in total
5 Gg increase in NH_x
53 Gg decrease in NIT



116 Gg decrease in total
42 Gg decrease in NH_x
74 Gg decrease in NIT

Nitrate vulnerable zones in England



Source:
https://environment.data.gov.uk/farmers/

Concluding Remarks and Recommendations

$PM_{2.5}$ is overwhelmingly dominated by agricultural emissions of ammonia (NH_3) in urban and rural environments across the UK

Current legislation still strictest for sources of primary $PM_{2.5}$ and sulfur dioxide forming sulfate aerosols and nitrogen oxides forming nitrate aerosols

Emissions changes resulting from current legislation are ineffective at addressing ammonia emissions, resulting in modest declines in $PM_{2.5}$

With more ambitious measures targeting agricultural NH_3, public health gains of ~22,000 avoided premature deaths and decline in a quarter of current total nitrogen deposition could be achieved

Such gains can be broadly applied to other parts of the world that have focused on all but agricultural air pollution sources