Assessment of UK Ammonia Emissions with Satellites

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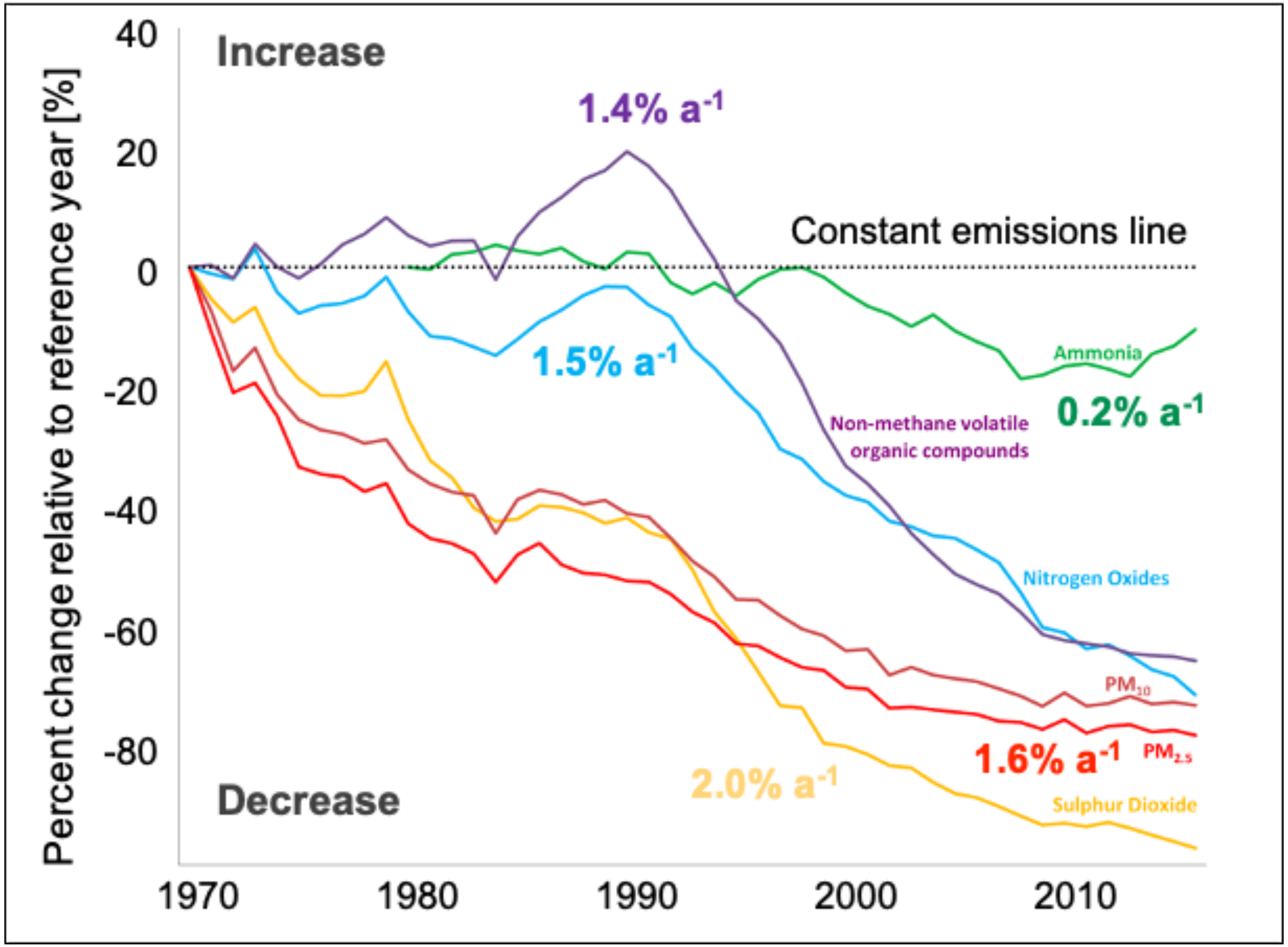
UCL

Ammonia Emissions in the UK: the Bottom-Up Perspective

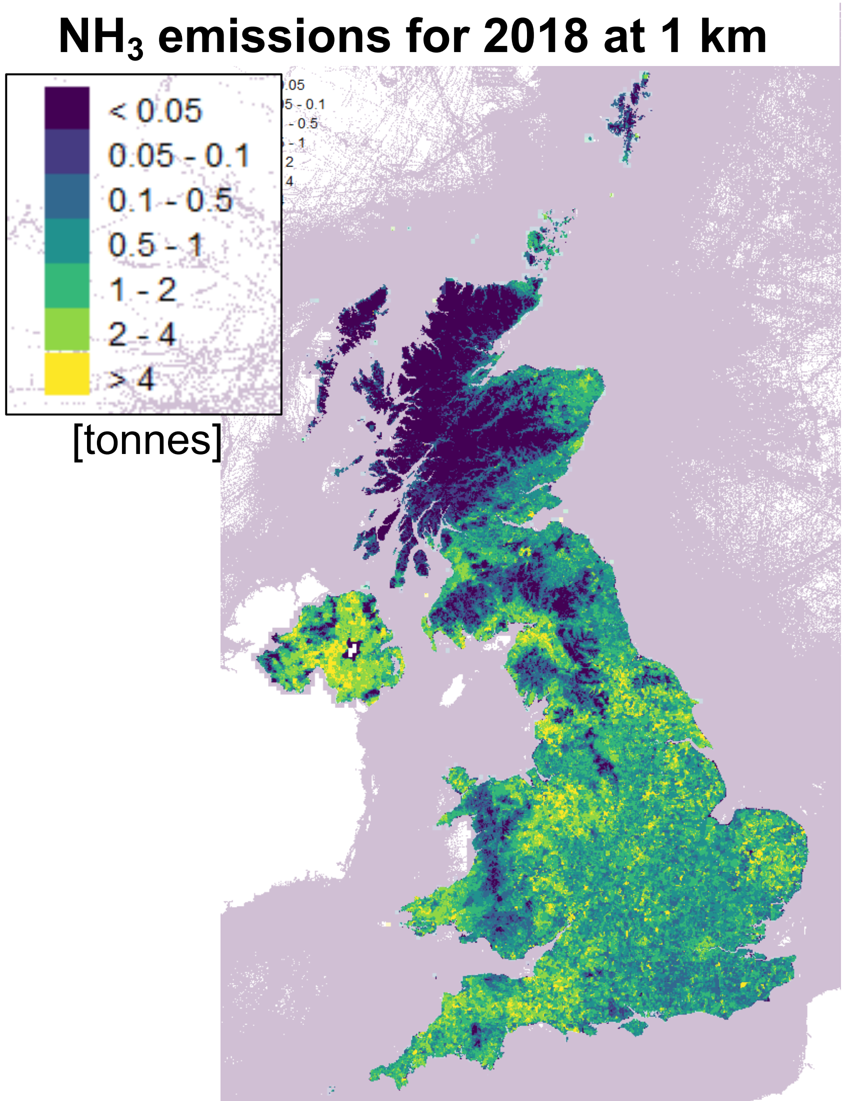
Temporal (Time) Variability in Emissions



[*Adapted from* Defra, 2018]

Spatial Variability in Emissions

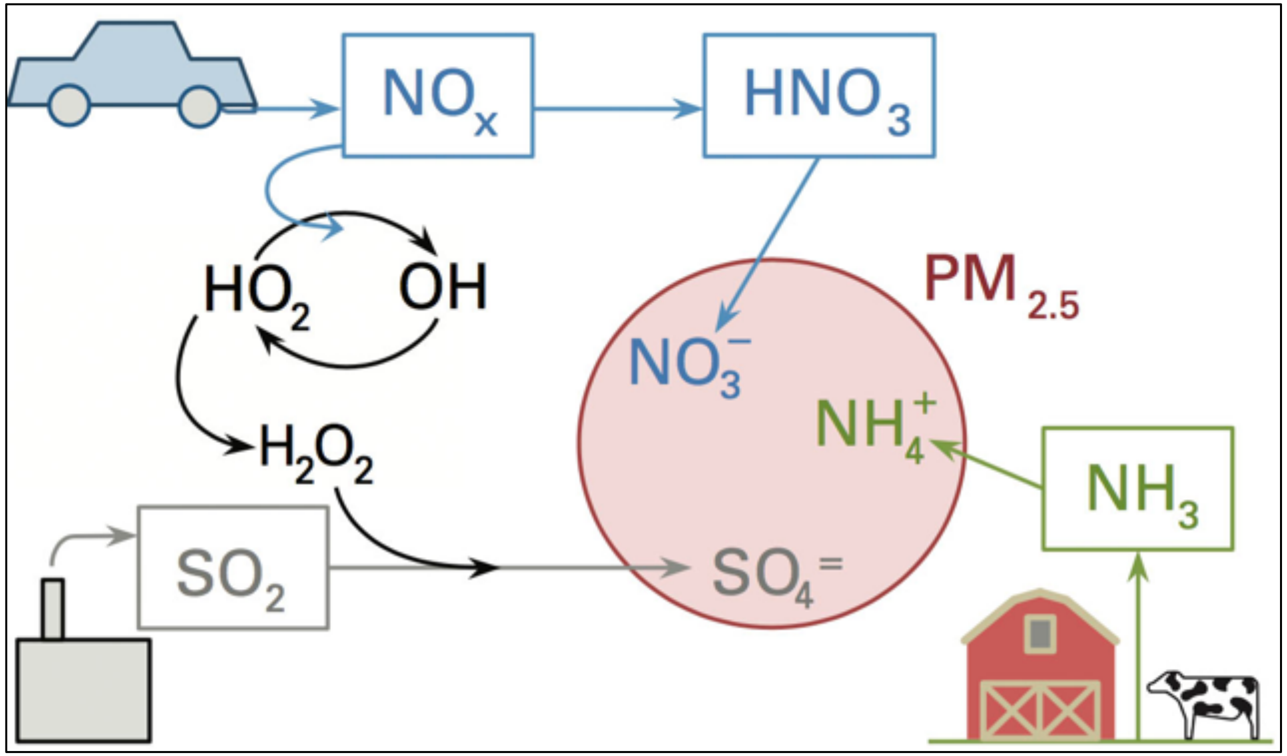
NH_3 emissions for 2018 at 1 km



[*Adapted from* https://naei.beis.gov.uk/data/]

Ammonia Impact on Air Quality

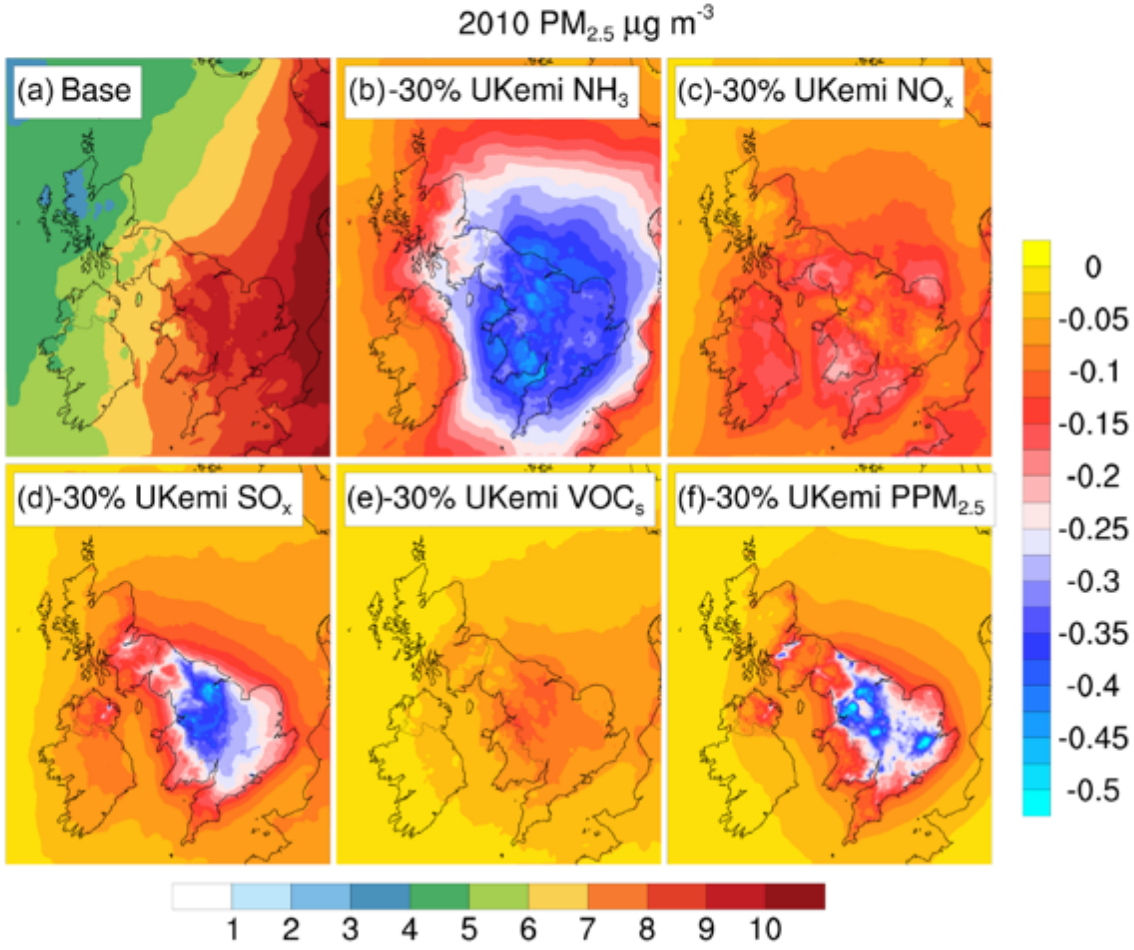
Ammonia partitions to aerosols to form $PM_{2.5}$



[http://climate-science.mit.edu/]

Partitioning of ammonia (NH_3) to pre-existing aerosols depends on abundance of NO_x and SO_2

Effect of emission controls on $PM_{2.5}$



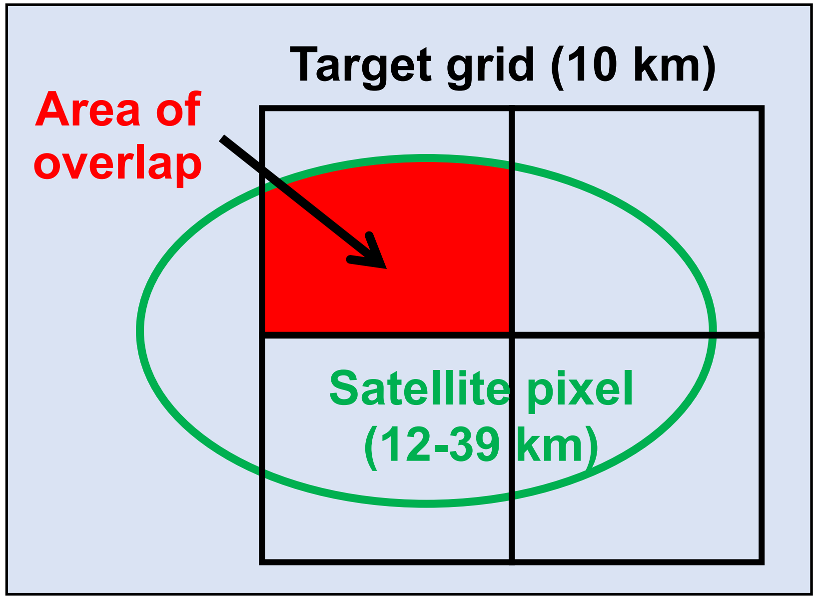
[Vieno et al., 2016]

Largest and most extensive decline in $PM_{2.5}$ achieved by targeting ammonia sources

Ammonia Emissions in the UK: the Top-down Perspective

Enhance the spatial resolution relative to the native resolution of the instrument by oversampling

Oversampling Technique

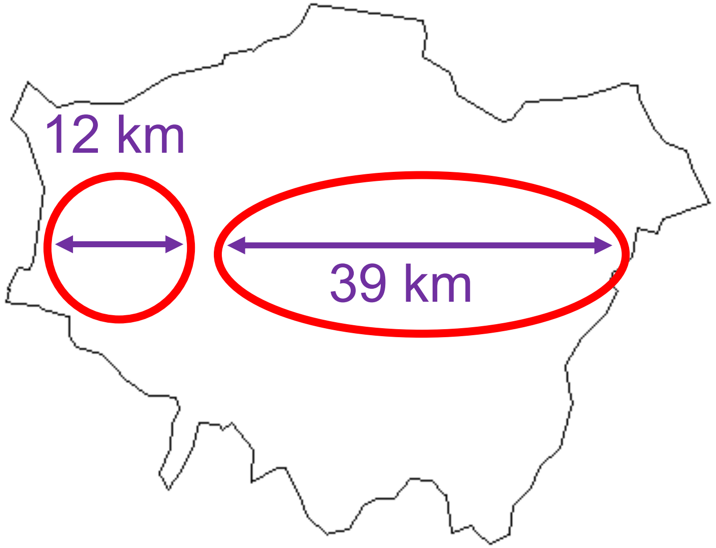


Weights each IASI NH_3 pixel by area of overlap and the reported uncertainty

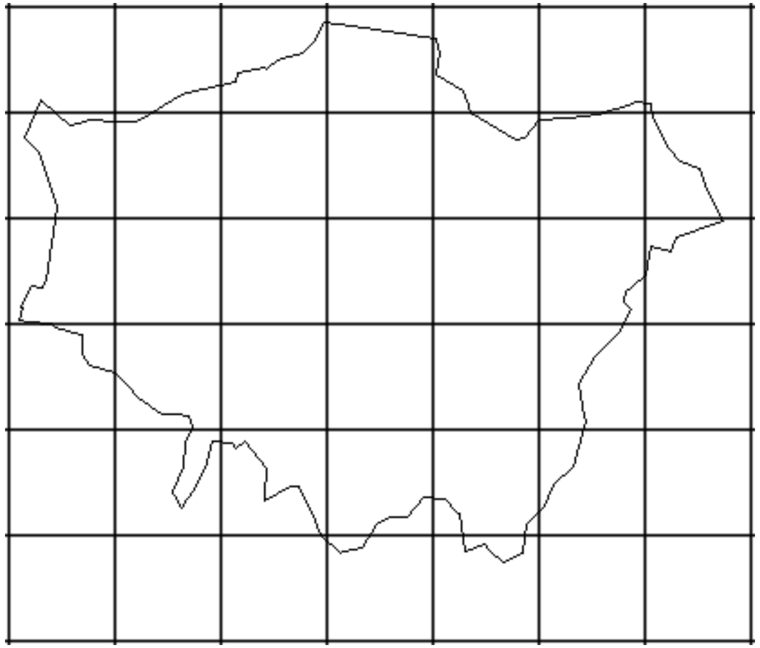
Oversampling code: L. Zhu, SUSTech (Zhu et al., 2017)

Oversampling technique over London

IASI ground pixel



0.1° x 0.1° (~10 km) grid

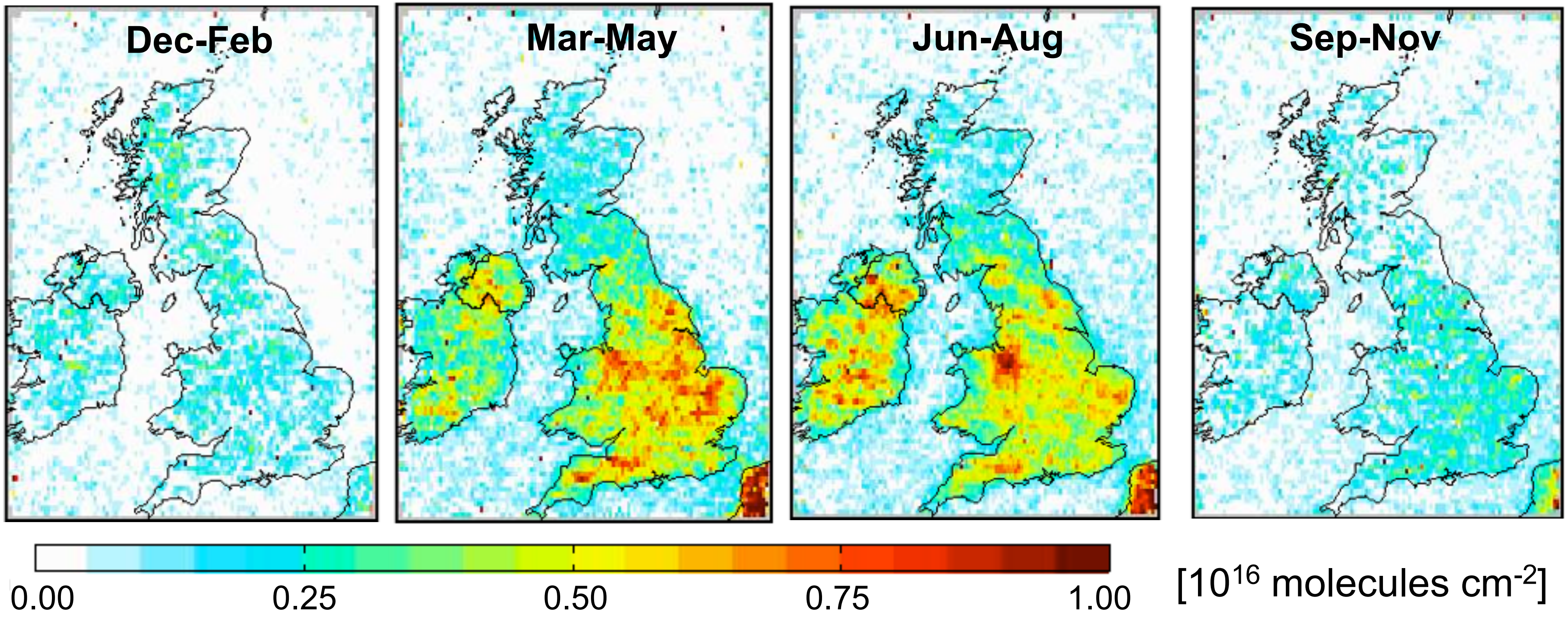


Lose time (temporal) resolution; gain spatial resolution

Ammonia Emissions in the UK: the Top-down Perspective

Observations of column densities are available since 2007 from the IASI instrument

Annual multiyear (2008-2018) mean IASI NH_3 on a 0.1° x 0.1° (~10 km) grid



Units are number of ammonia molecules in a column of air from the surface to the satellite

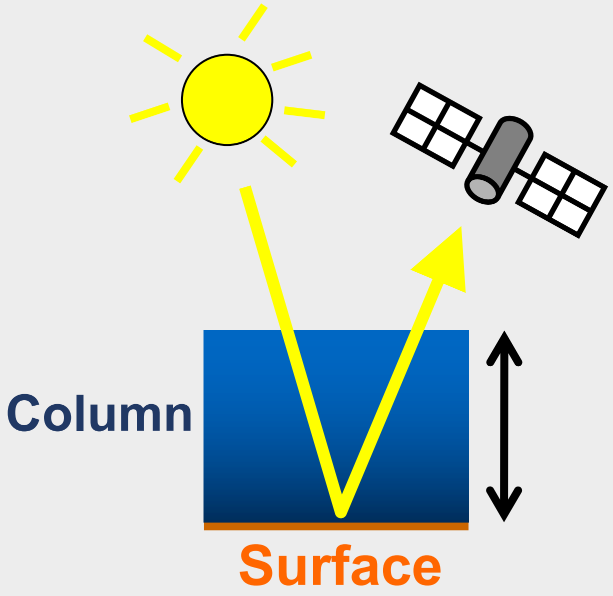
IASI data providers: M. Van Damme, L. Clarisse, P.-F. Coheur, ULB, Belgium

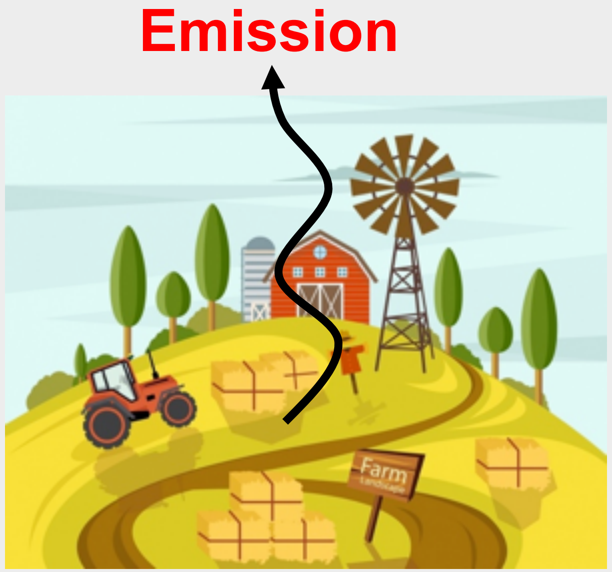
Top-down Emissions Estimates from Satellite Observations

Convert atmospheric **column concentrations** to surface **emissions** by relating the two using a **model**

ABUNDANCES → **Conversion Factor** → **EMISSIONS**

Satellite column densities → **Model Concentration-to-Emission Ratio** → **Satellite-derived Surface Emissions**





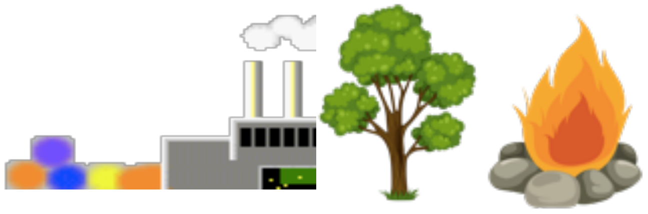
Approach used widely: convert column concentrations of NO_2 to surface emissions of NO_x, convert column concentrations of **formaldehyde** to surface emissions of **isoprene** from vegetation

Conversion Factor Obtained with GEOS-Chem

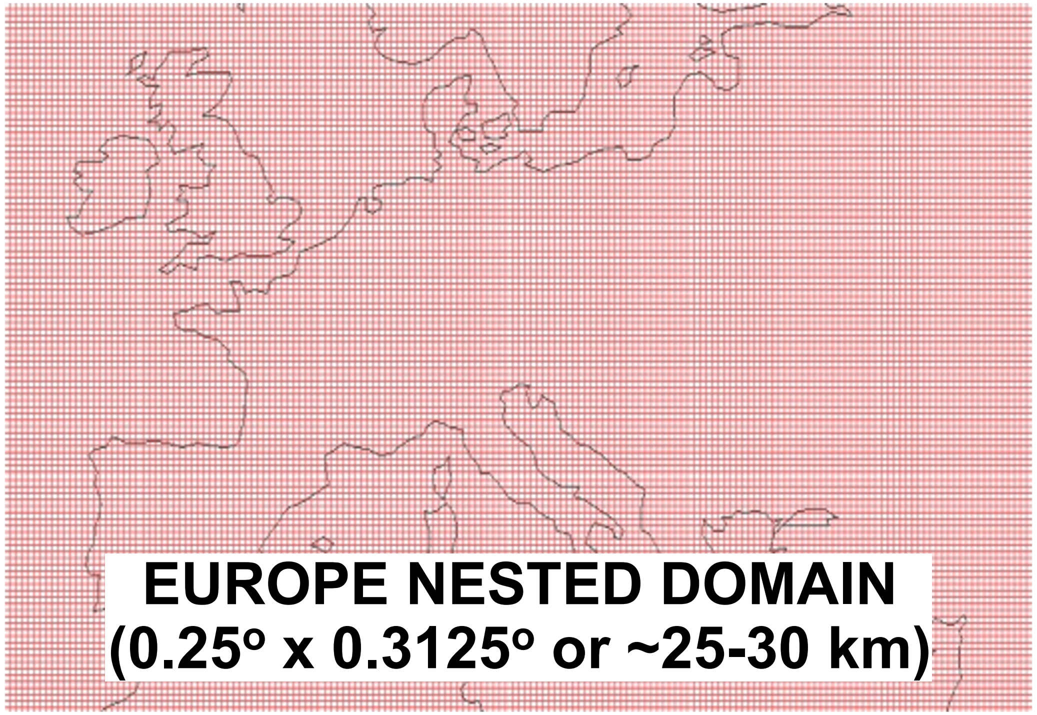
GEOS-Chem

3D Atmospheric Chemistry Transport Model

Emissions (natural/human)



UK NAEI for 2016
EMEP for mainland Europe
(with temporal scaling factors)



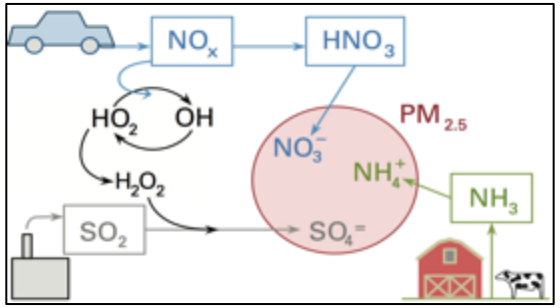
Offline assimilated meteorology

NASA GEOS-FP for 2016

Gas phase and heterogeneous chemistry
Transport
Dry/wet deposition

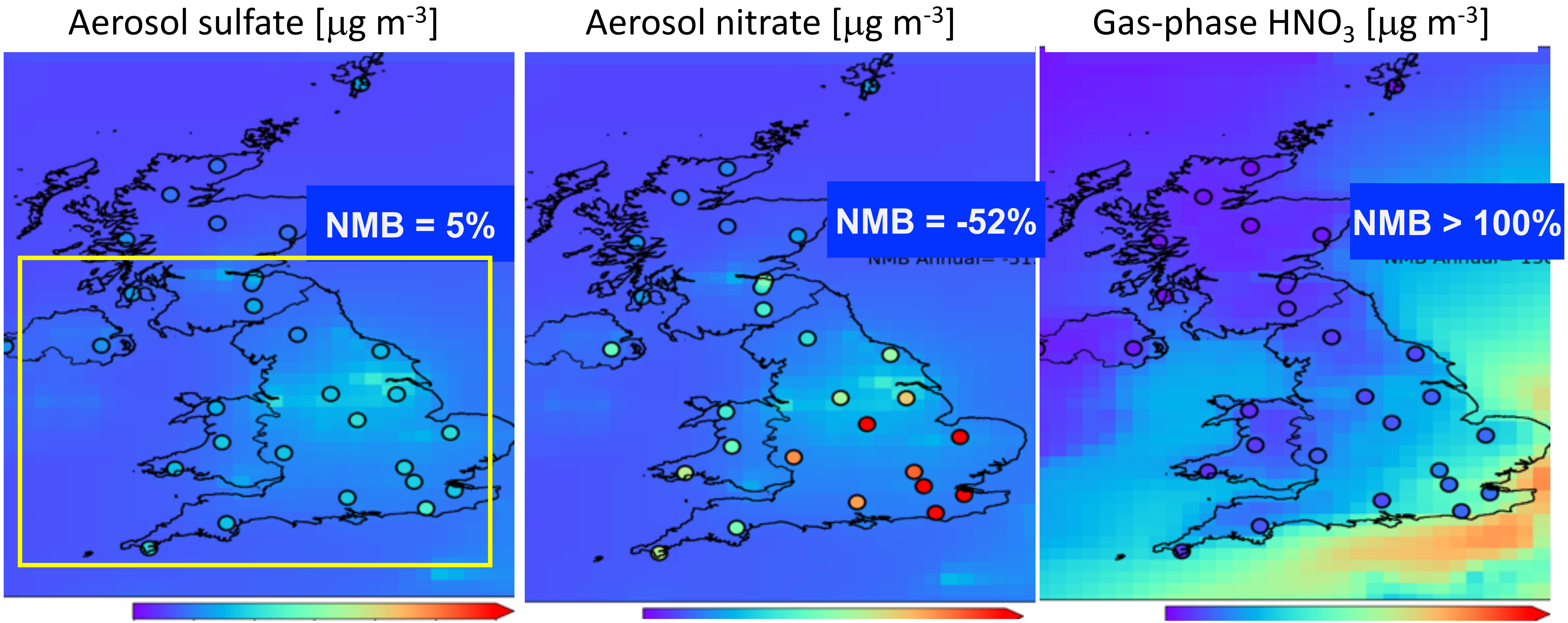
GEOS-Chem **version 12.1.0** (doi:10.5281/zenodo.1553349)

Evaluate Model with Surface Observations



Evaluating GEOS-Chem NH_3 alone is insufficient

Also need to consider SO_2, **sulfate**, **HNO_3**, **nitrate**, and **ammonium**

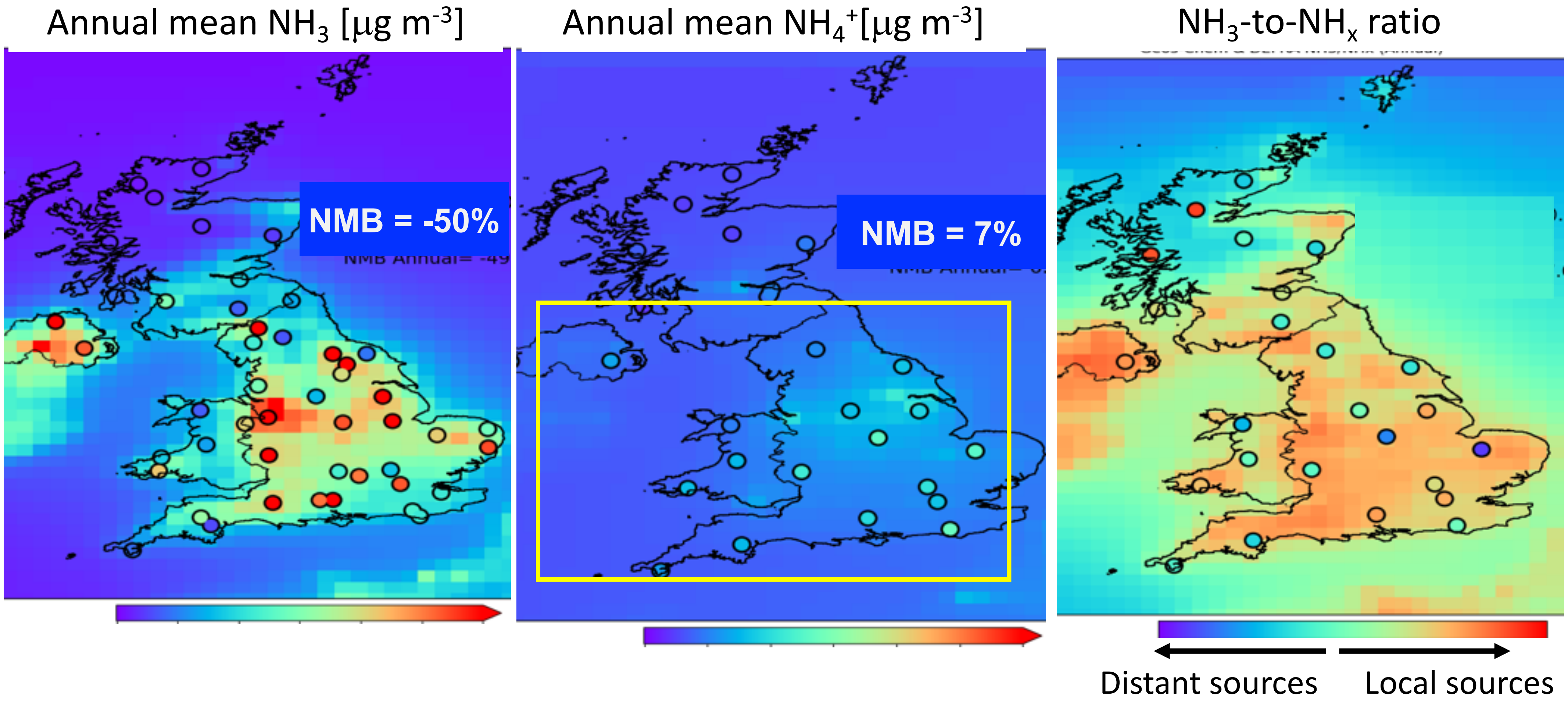


NMB: Model mean bias

[Circles: UKEAP surface network]

Results from comparison suggests model conversion of HNO_3 to aerosol nitrate is underestimated

Evaluate Model with Surface Observations



NMB: Model normalized mean bias

[Circles: UKEAP surface network]

Model with NAEI NH_3 emissions is missing elevated NH_3 concentrations in Southeast UK

Throughout the UK, the model underestimates NH_x (NH_3 + ammonium)

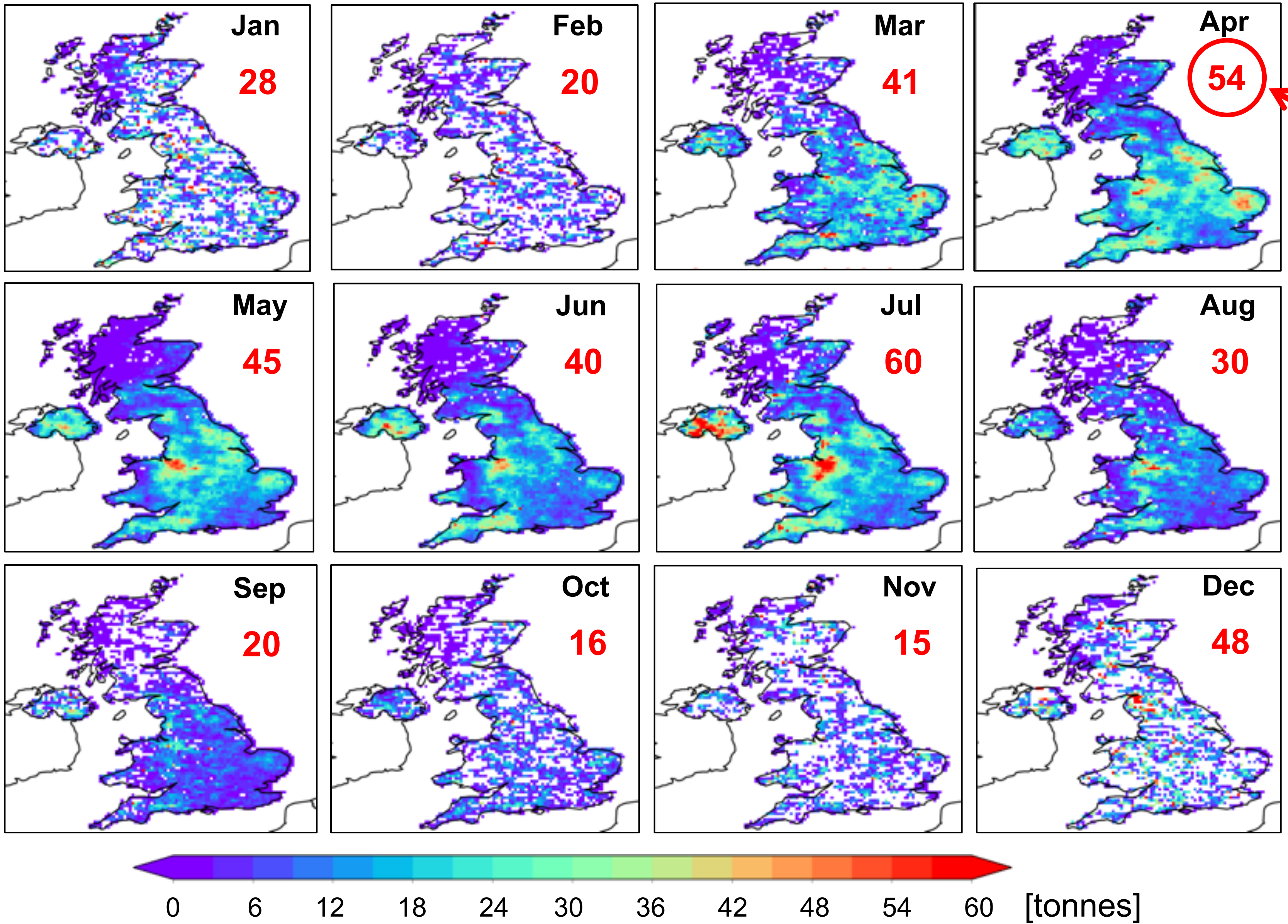
May be the cause for the underestimate (overestimate) in nitrate (HNO_3)

UK IASI-derived Ammonia Emissions

Convert IASI NH_3 column concentrations to surface emissions of NH_3

Data noisy in winter, start of spring, and end of autumn

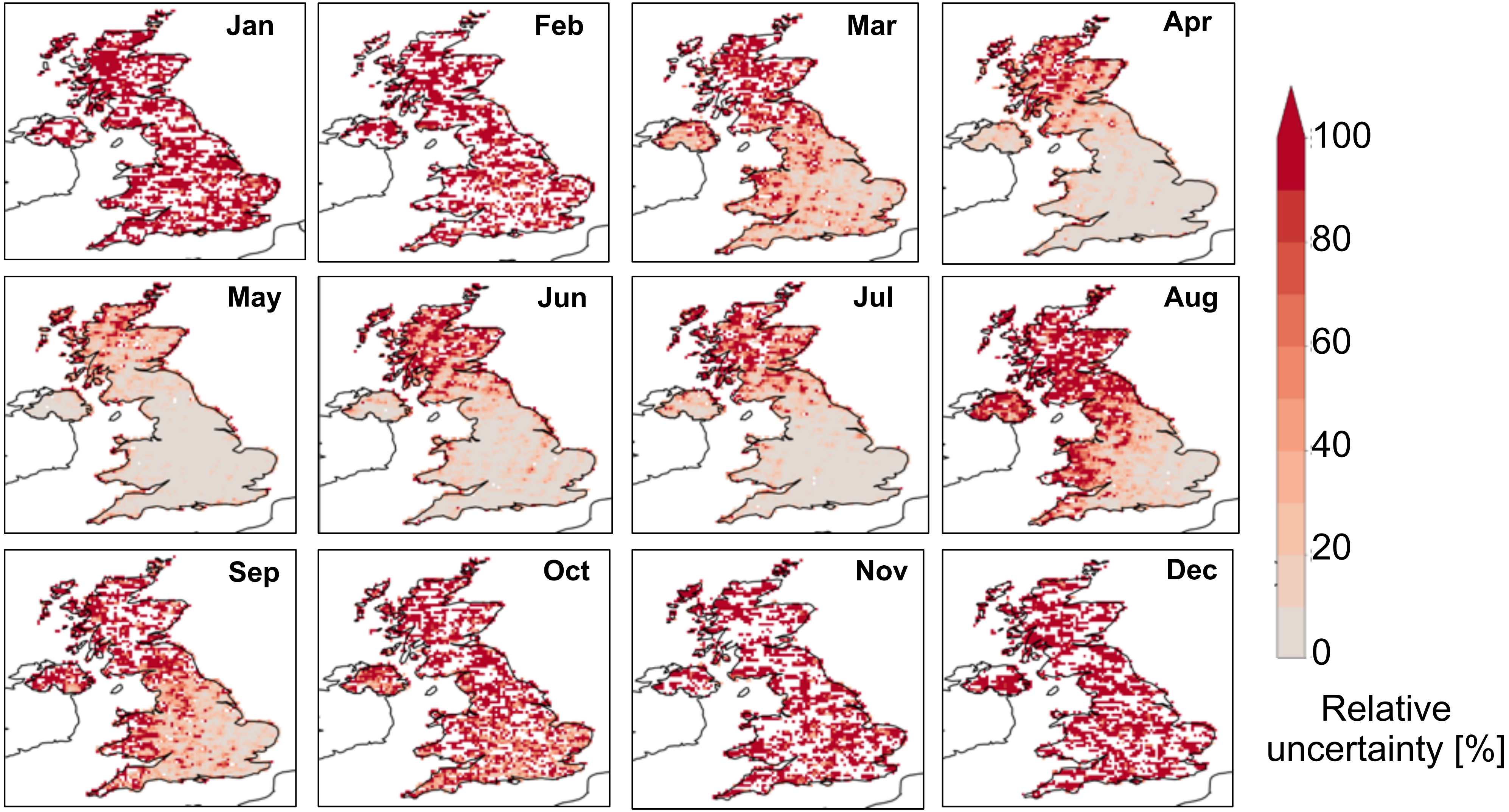
Challenging to retrieve NH_3 in these months



Total monthly emissions

Account for Observation Uncertainties

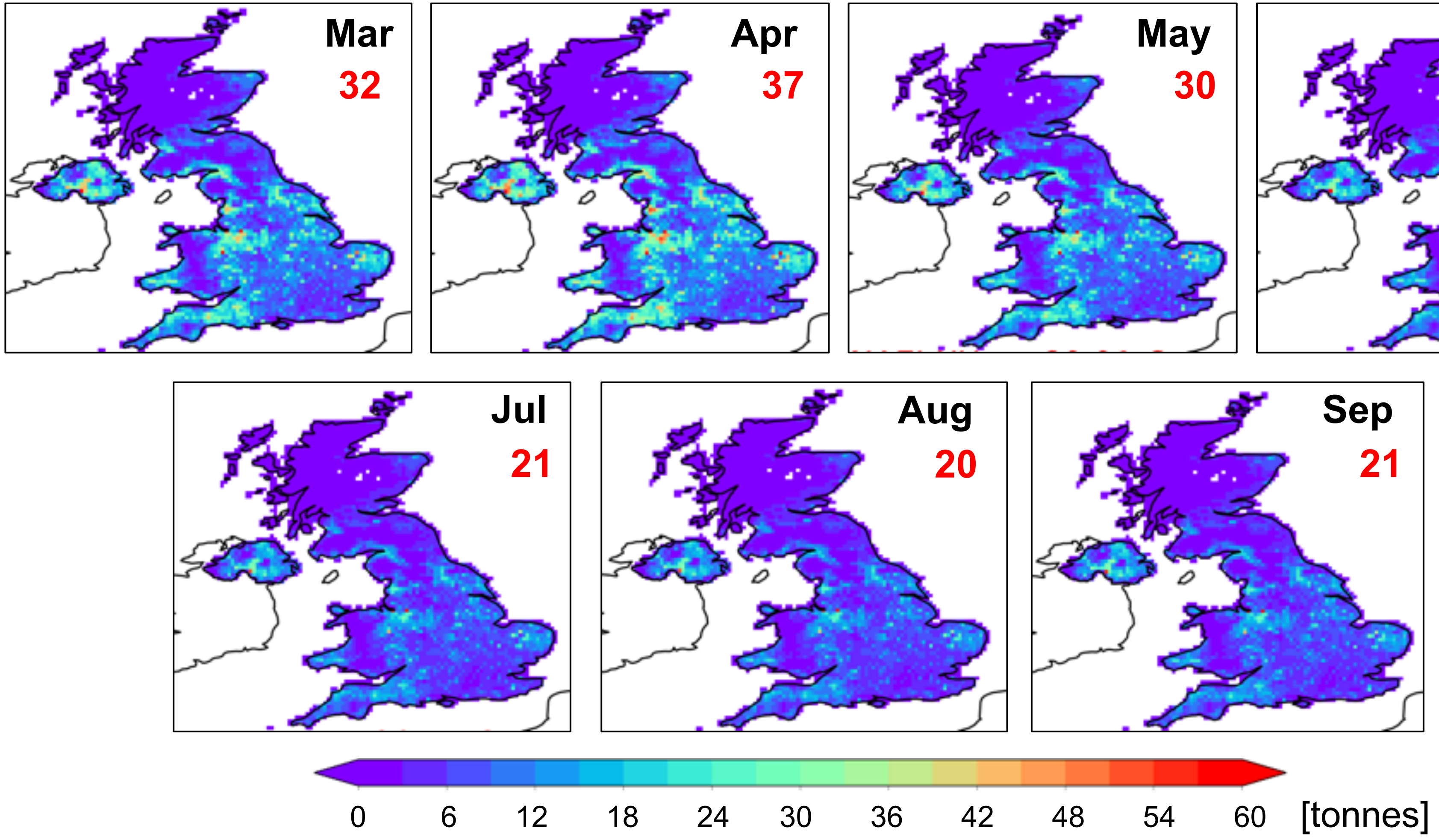
IASI NH_3 column concentrations susceptible to large uncertainties in cold months



Only consider months with relatively low uncertainty: March-September

NAEI Ammonia Emissions

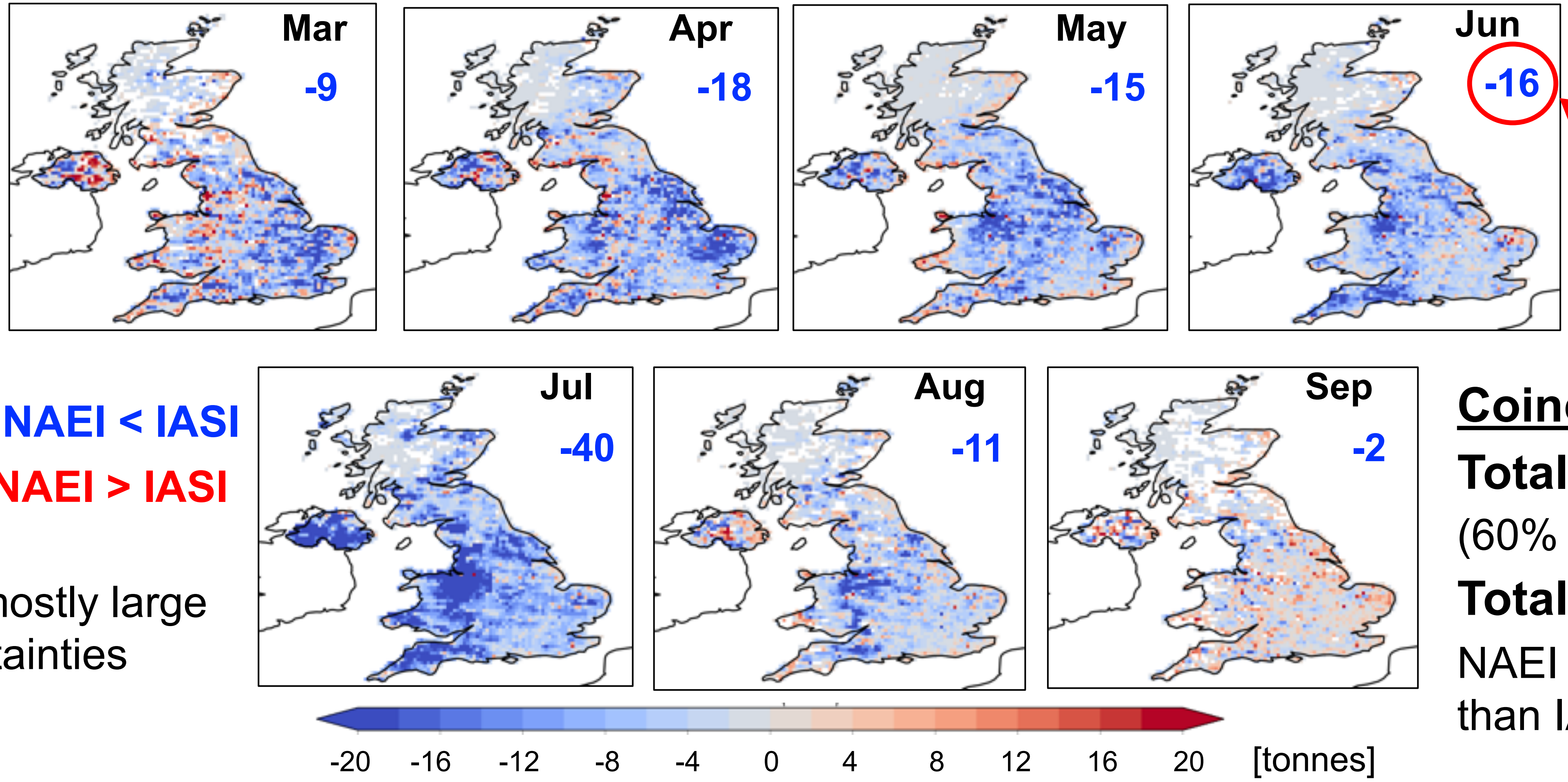
NAEI NH_3 emissions with monthly scaling factors used in GEOS-Chem applied



NAEI NH_3 emissions in March-September are 67% of annual NAEI NH_3 emissions

Assessment of the UK National Emission Inventory

Compare IASI-derived and NAEI NH_3 emissions with representative scaling factors applied to the NAEI



Difference in monthly emissions

Blue: NAEI < IASI

Red: NAEI > IASI

Red mostly large uncertainties

<u>Coincident grids:</u>

Total NAEI: 174 Gg (60% of 2016 total)

Total IASI: 290 Gg

NAEI 1.6 times less than IASI

Reported error for NAEI ammonia is 31%. We still need to calculate uncertainty in IASI emissions.

Next we will evaluate underlying dominant agricultural activity over locations with large discrepancies

Acknowledgements

Defra for funding

Alok Pandey for the bulk of the data analysis

Martin Van Damme, **Lieven Clarisse**, and **Pierre-F. Coheur** for IASI NH_3

Lei Zhu for oversampling code

UKEAP team that maintains the very precious surface monitoring network

Any Queries? Please contact me at e.marais@ucl.ac.uk

To find out more about past and ongoing research visit:
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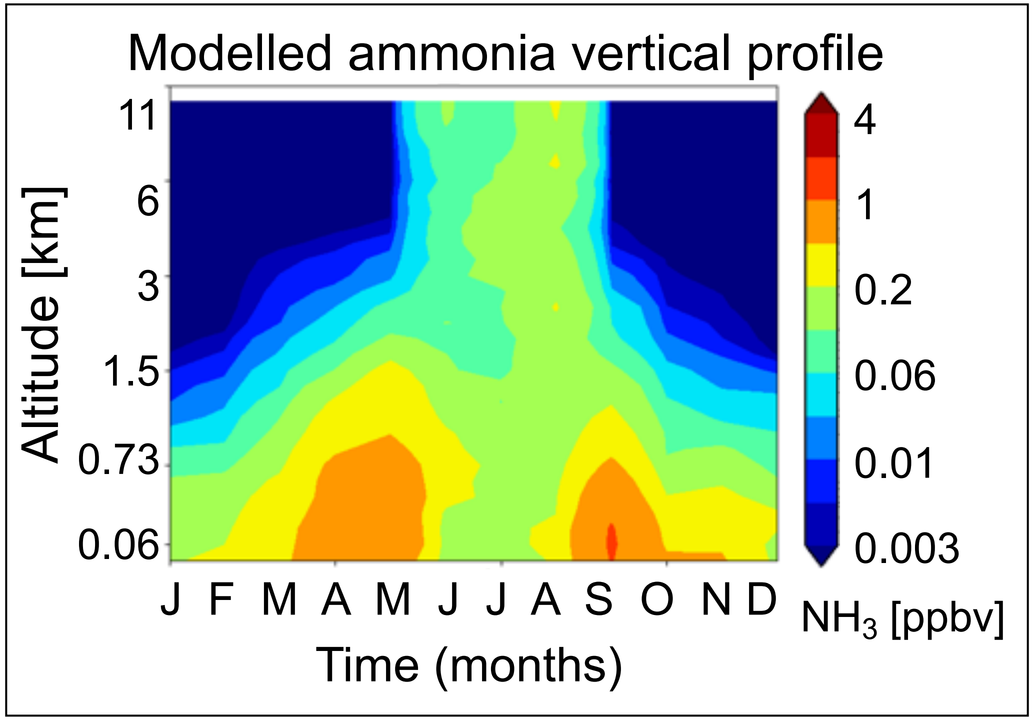
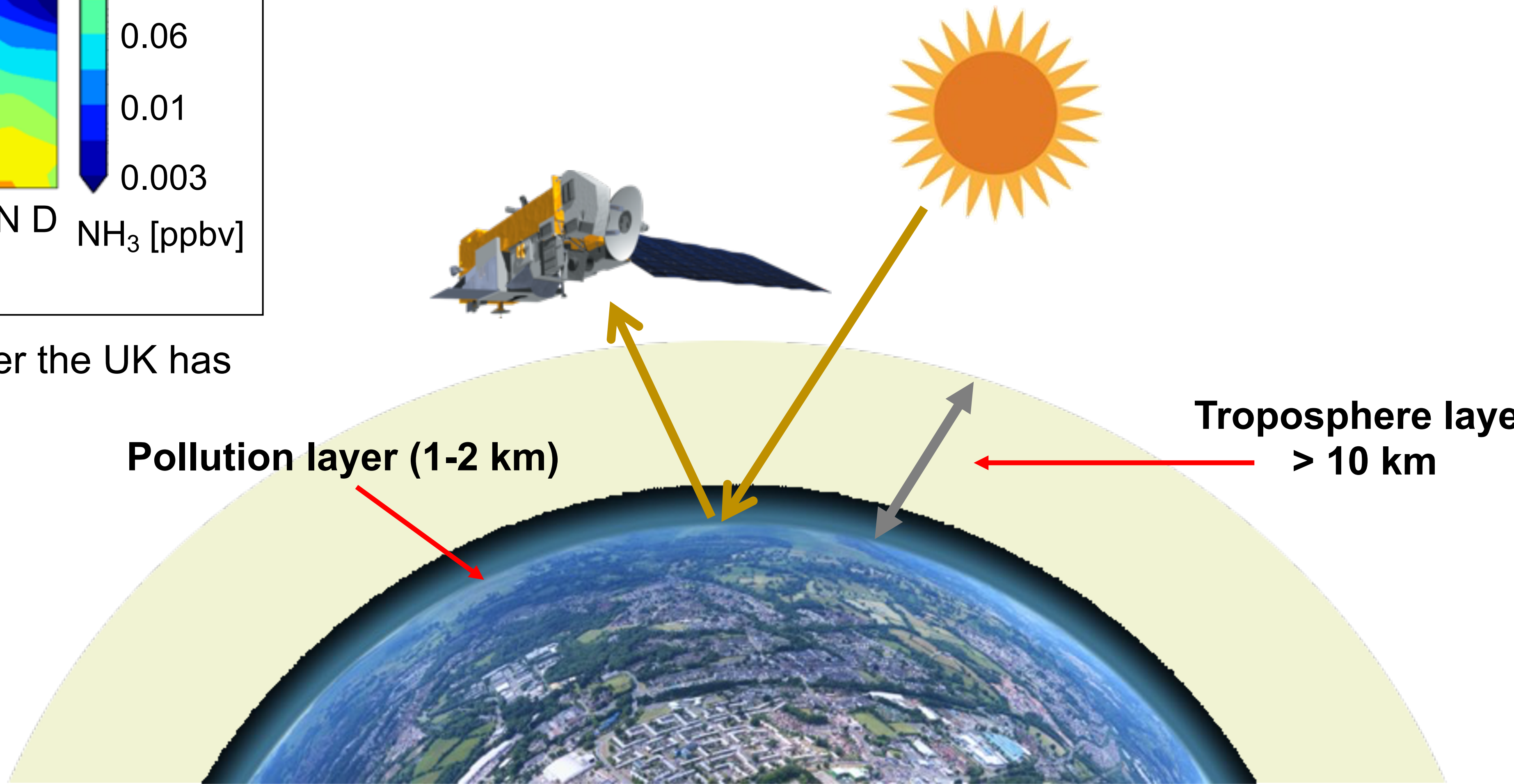
Extra Slide 1



IASI observes ammonia throughout the atmospheric column

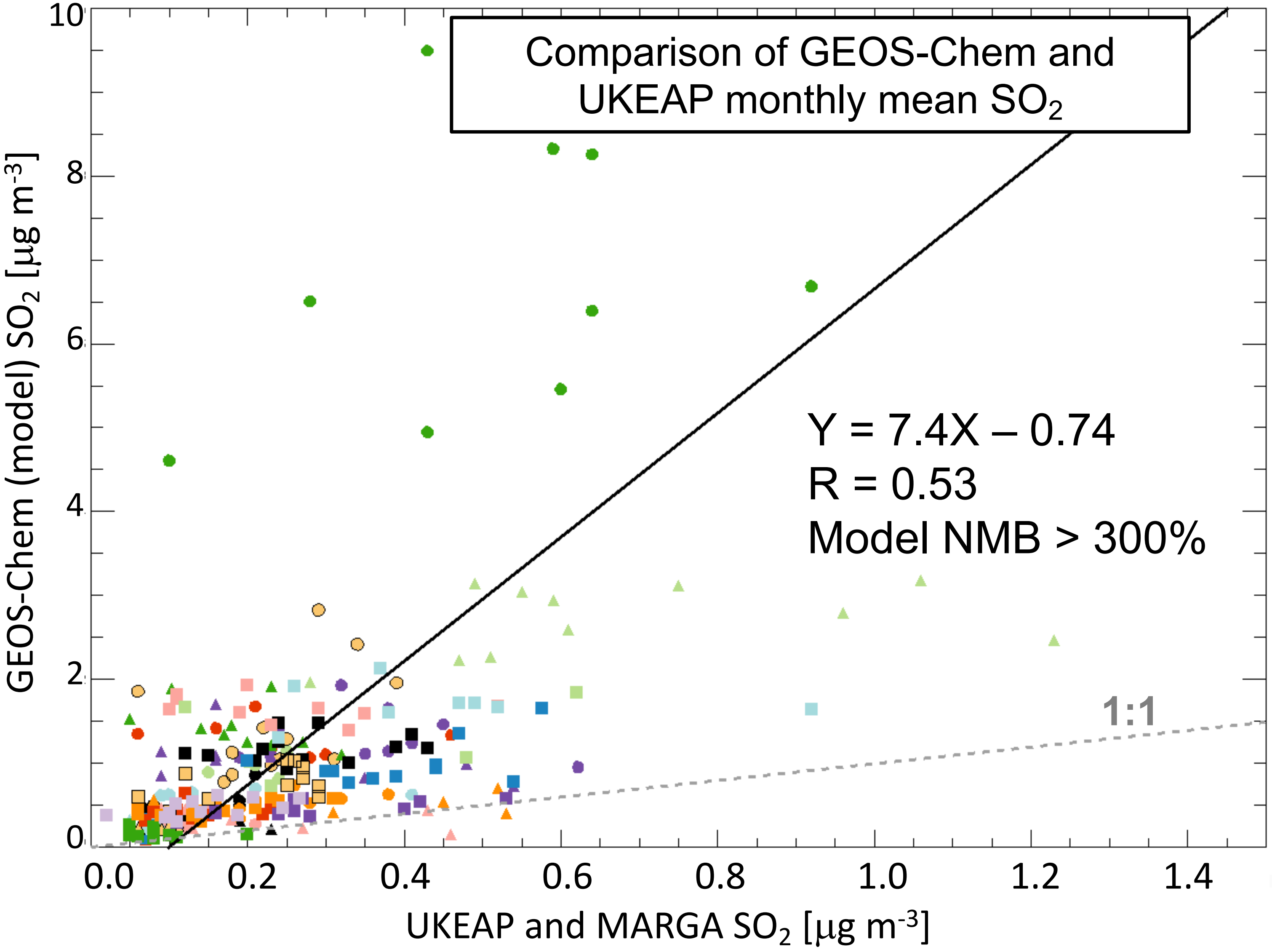
Model relates column concentration to surface emissions by accounting for complex dynamics of ammonia (chemistry, physical processing, weather)

Ammonia vertical distribution over the UK has seasonal variability



Extra Slide 2

Point source emissions of SO_2 may be overestimated in the UK NAEI



UKEAP sites and NAEI SO_2 emissions