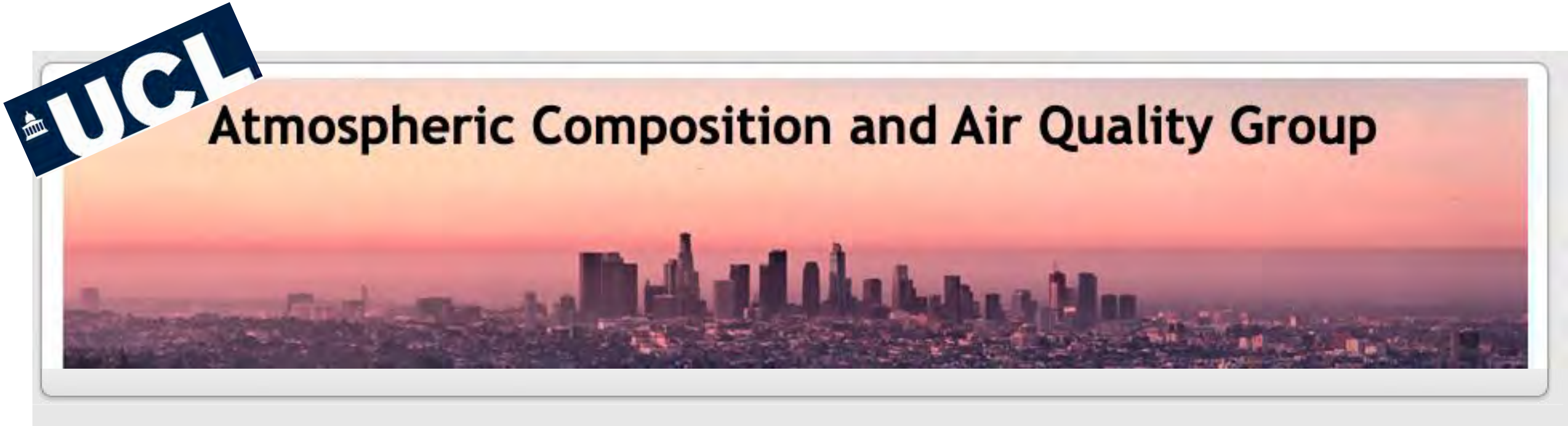
Current Emissions Estimate Capabilities with EO



https://maraisresearchgroup.co.uk/

Broad objective is to derive independent emissions estimates to compare to bottom-up (inventory) emissions to identify discrepancies that require further investigation

Disclaimer: Not exhaustive! Notable omission is long-lived pollutants (carbon monoxide) & greenhouse gases (methane, nitrous oxide and carbon dioxide)

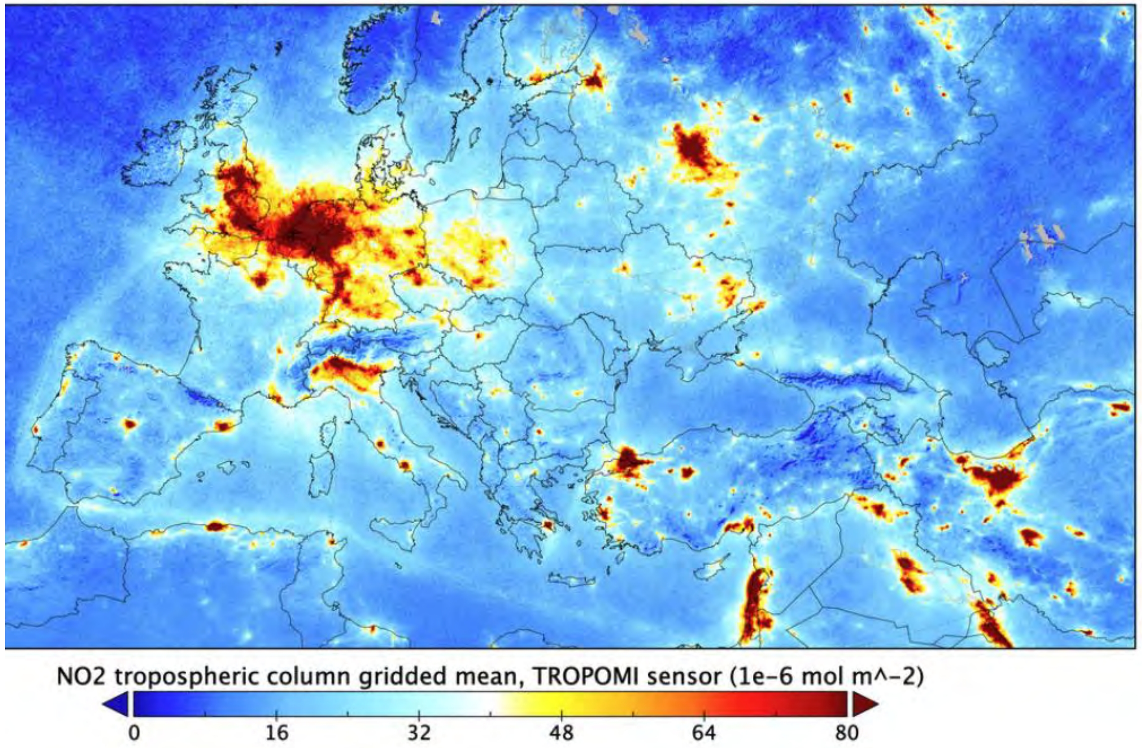
Eloise A. Marais (e.marais@ucl.ac.uk)

14 Nov 2024

Gridded or Area Emissions

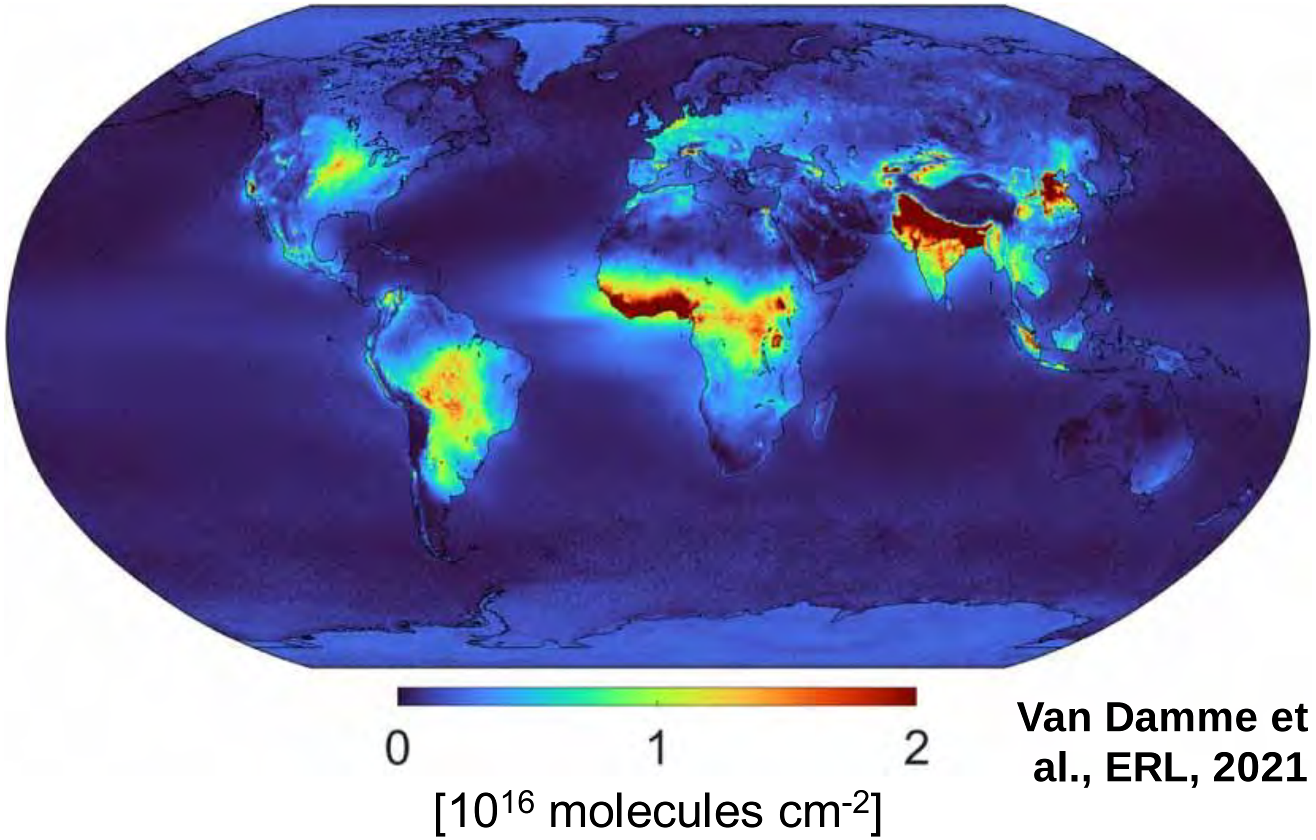
Satellite observations of air pollutants resolve hotspots and large area emissions

TROPOMI NO_2 on April 2018



TROPOMI NO_2 ATBD

IASI NH_3 on annual mean (2008-2018)



Van Damme et al., ERL, 2021

TROPOspheric Monitoring Instrument (TROPOMI):
UV-visible spectrometer with ~5-7 km resolution

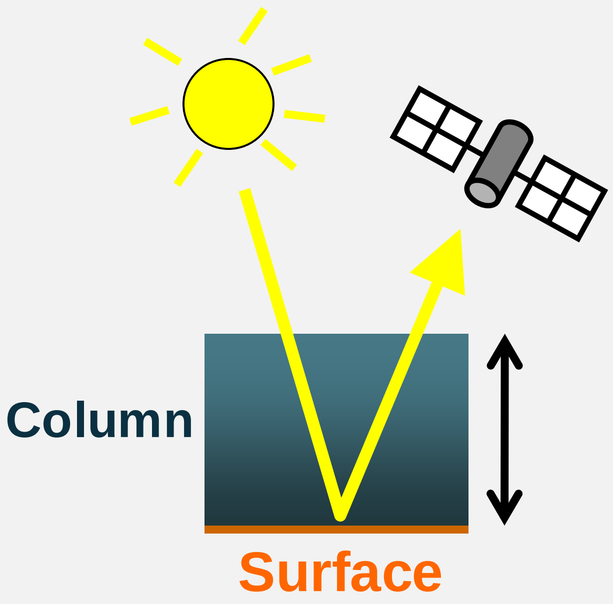
Infrared Atmospheric Sounding Interferometer (IASI):
Infrared spectrometer with ~13 km resolution

Gridded or Area Emissions

Convert atmospheric **column concentrations** to surface **emissions** using a **model**

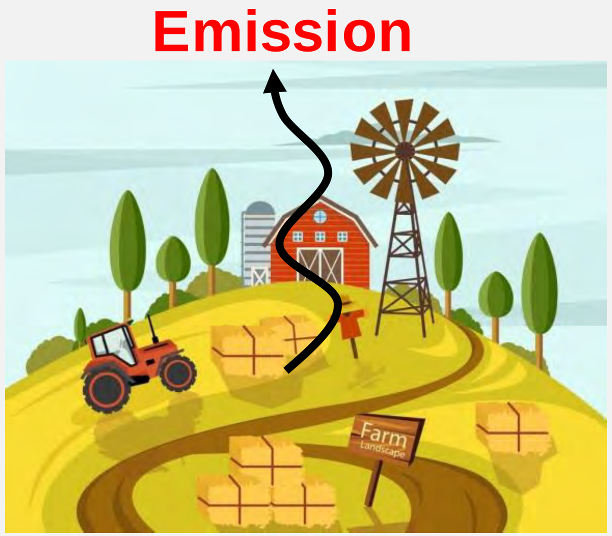
COLUMNS → **Conversion Factor** → **EMISSIONS**

Satellite columns



Column-to-Emission ratio (model)

Satellite-derived Surface Emissions

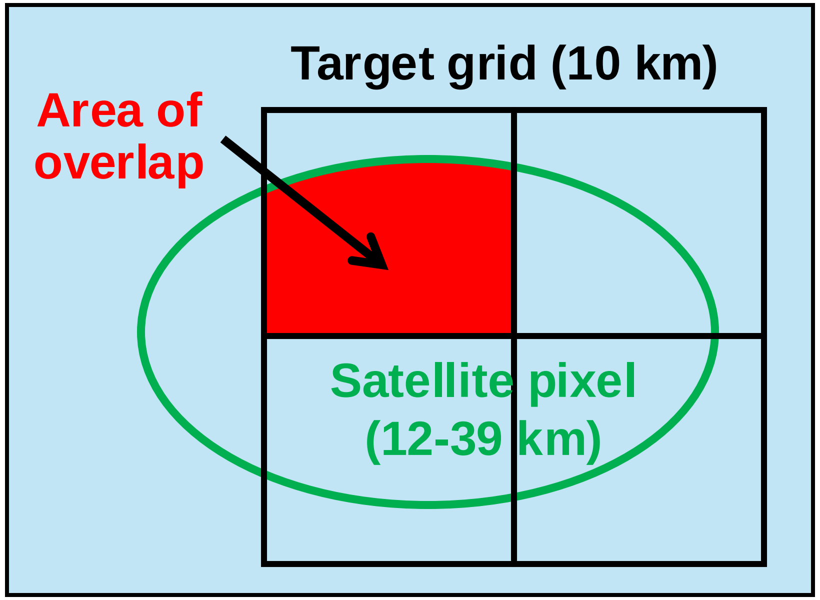


More complex inversion techniques using adjoints, machine learning, Lagrangian models tracking plumes

Preprocess to Grid to Finer Resolution than Instrument

Use so-called oversampling to enhance spatial resolution relative to native resolution of instrument

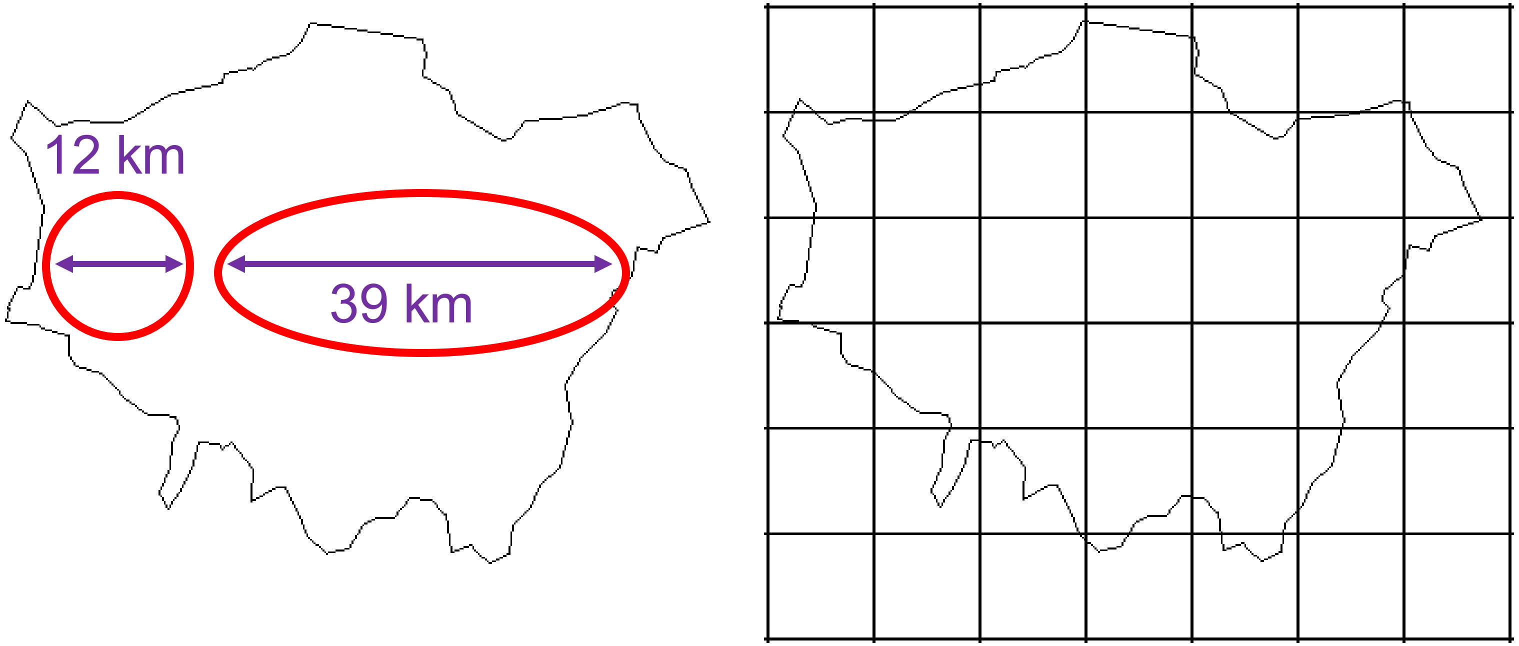
Oversampling Technique



Weights pixel by area of overlap

Oversampling technique over London

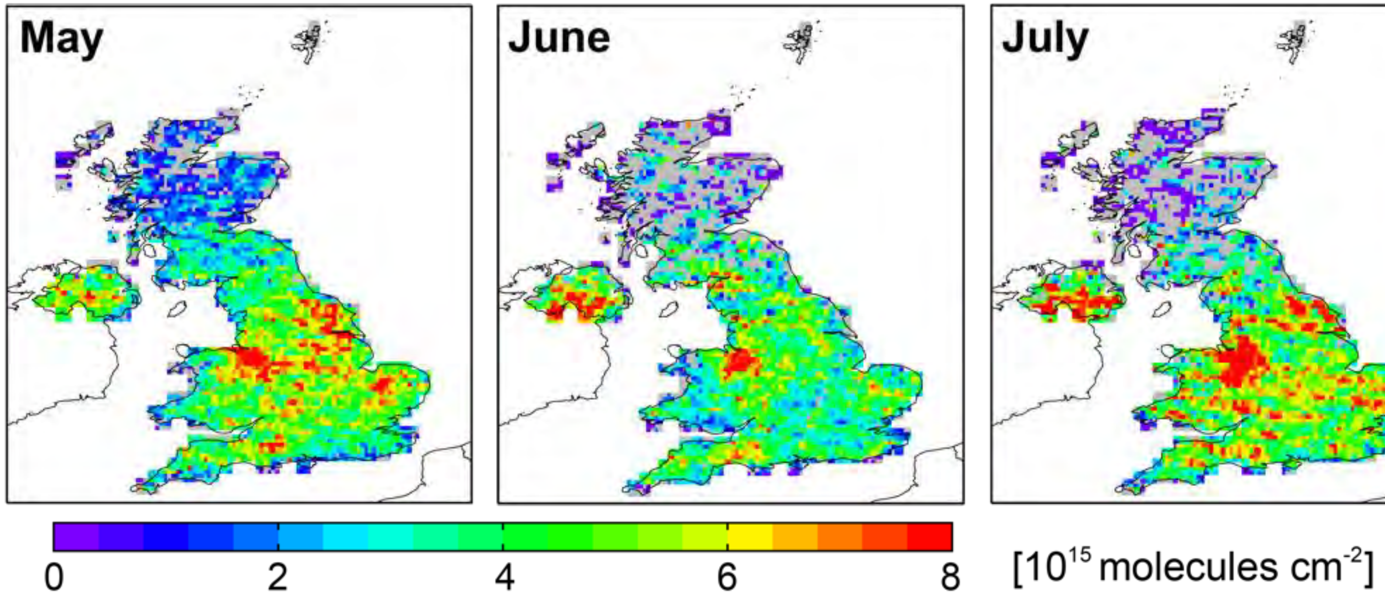
Satellite pixel resolution | **Fixed (~10 km) grid**



Lose time (temporal) resolution; gain spatial resolution

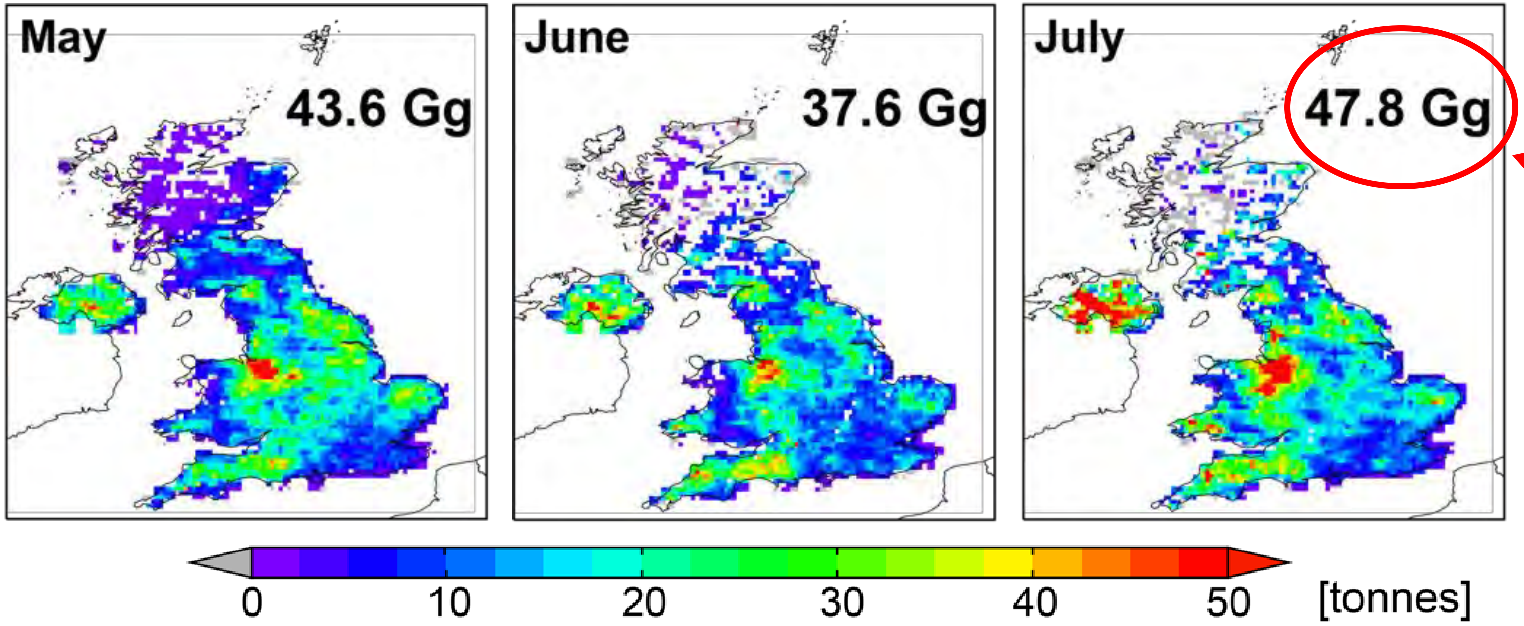
Improve resolution from 12-40 km to 10 km for an instrument observing ammonia (NH_3)

Gridded Emissions of Ammonia (NH_3) from Agriculture



Satellite instrument observations of ammonia (NH_3)

(Instrument: IASI or infrared atmospheric sounding interferometer)



Satellite-derived emissions of ammonia (NH_3)

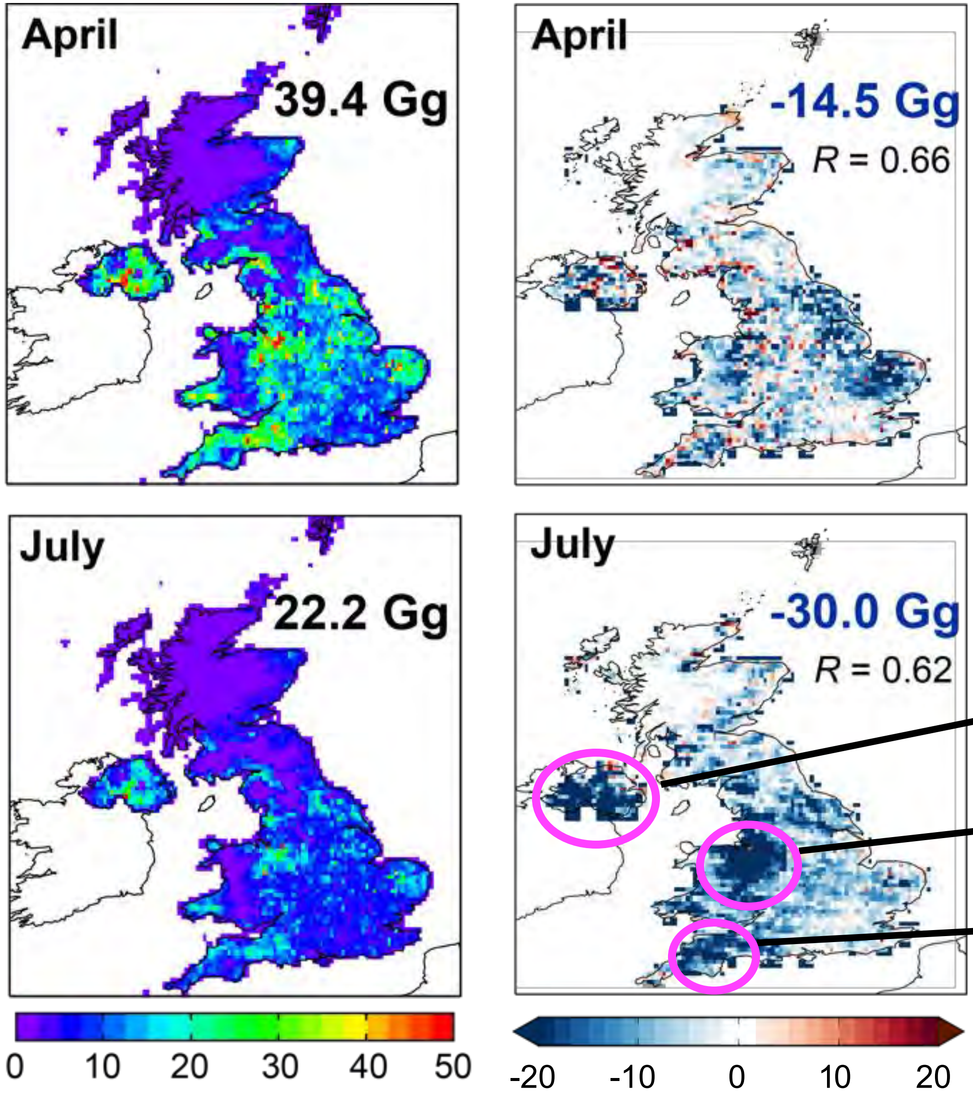
Total monthly emissions
(1 Gg = 1 kilotonne)

Marais et al., JGR, 2021

Satellite vs inventory NH_3 emissions: spatial distribution

Comparison of months with peak emissions according to IASI (April and July)

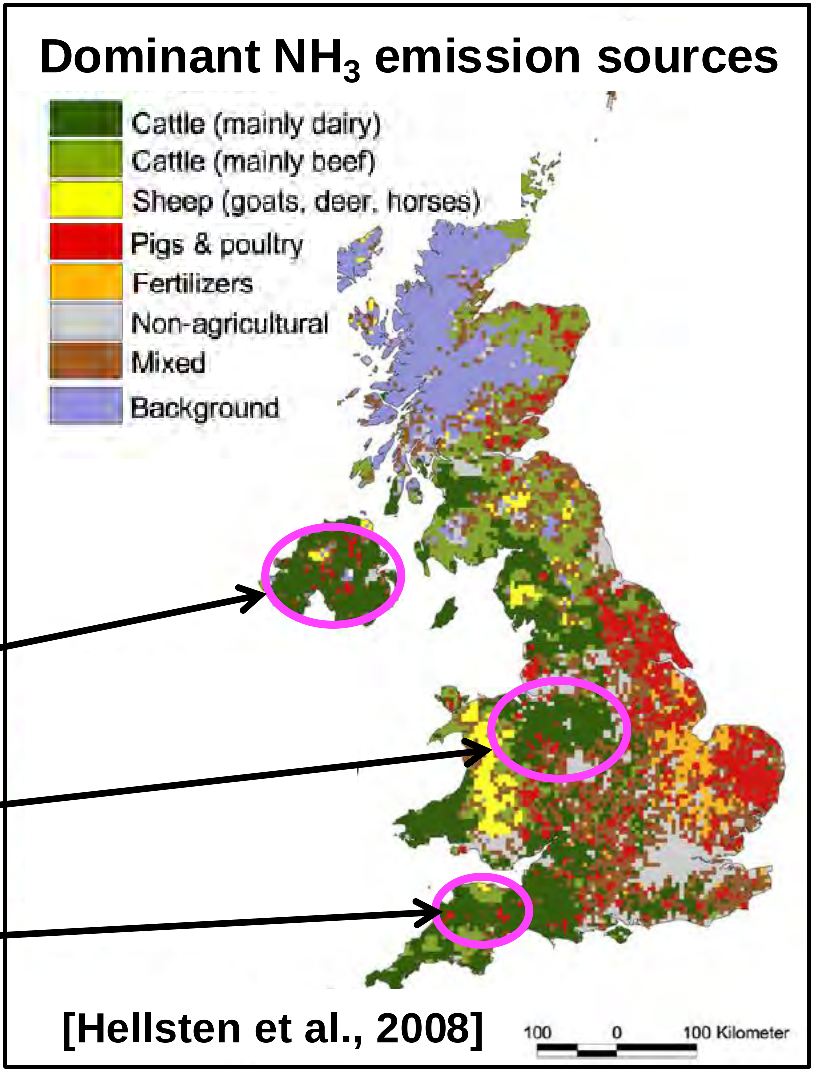
Bottom-up | **Bottom-up minus top-down**



Bottom-up < top-down

Top-down > bottom-up

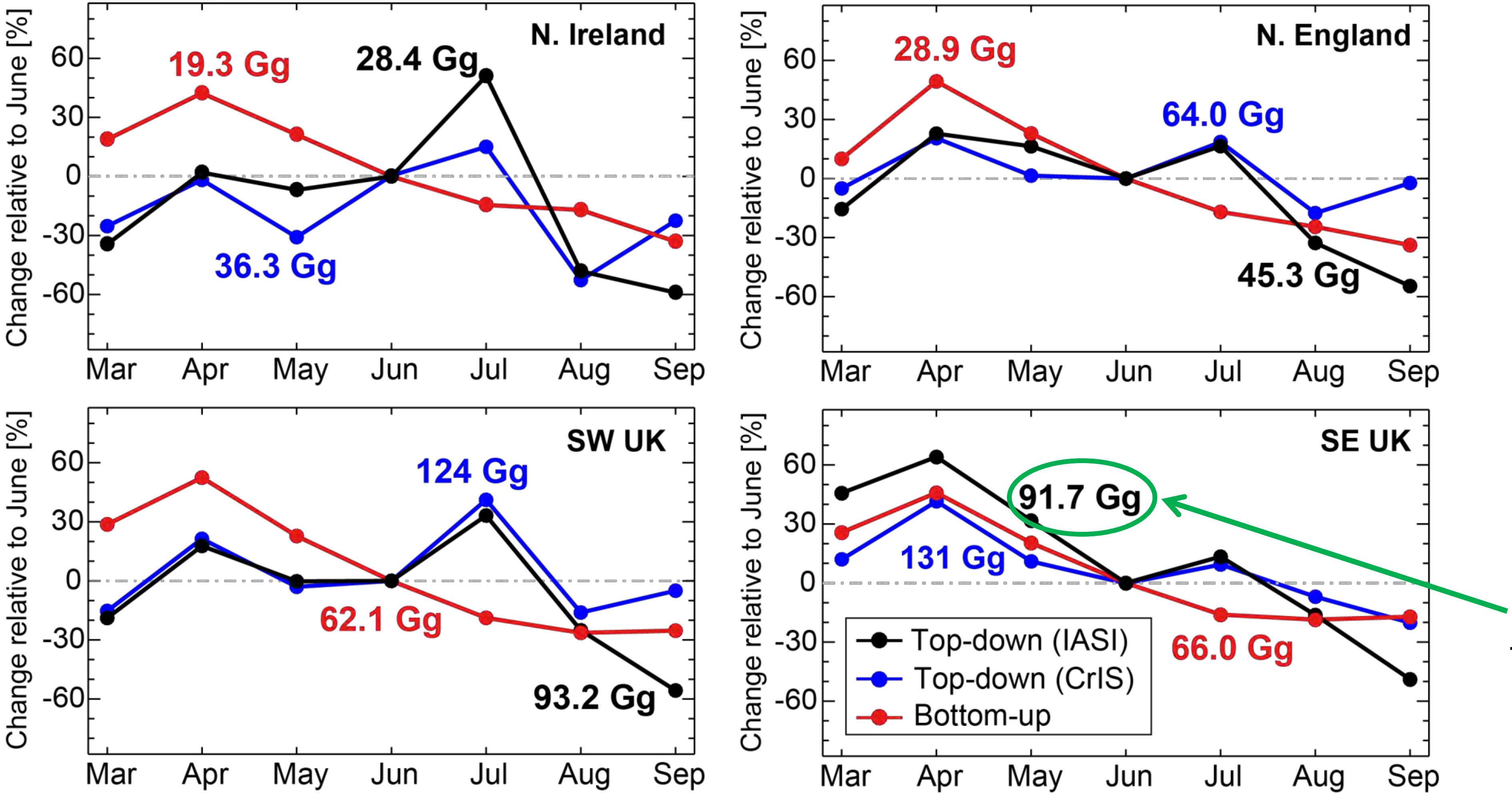
Marais et al., JGR, 2021



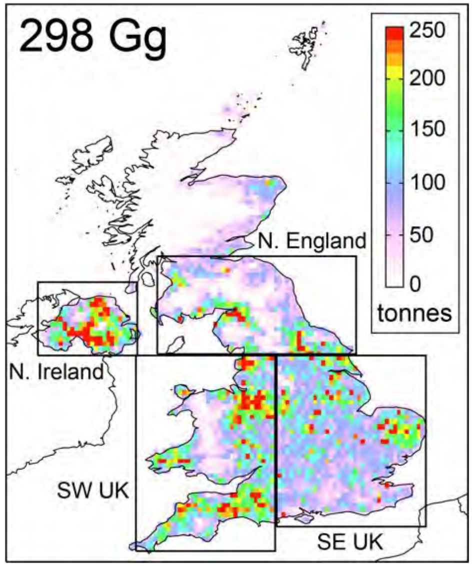
Large July difference over locations dominated by dairy cattle. Inventory is 27-49% less than the satellite values.

Satellite vs inventory NH_3 emissions: seasonality

Seasonality shown as emissions in each month relative to June



Regions and annual inventory emissions



Mar-Sep emission totals in each region

1 Gg = 1 kilotonne

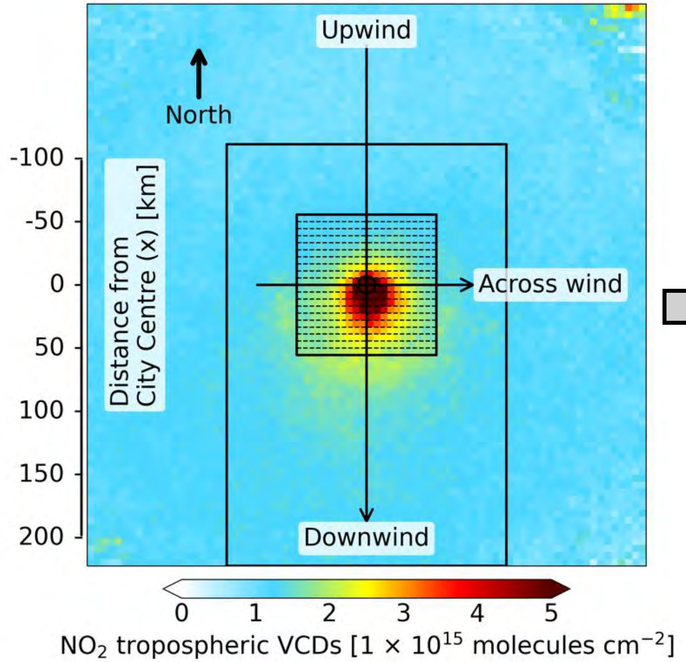
All reproduce spring April peak (fertilizer & manure use). Only the satellite show summer July peak (dairy cattle?).

The increase in emissions in September in CrIS is spurious.

Point Source or Hotspot Emissions

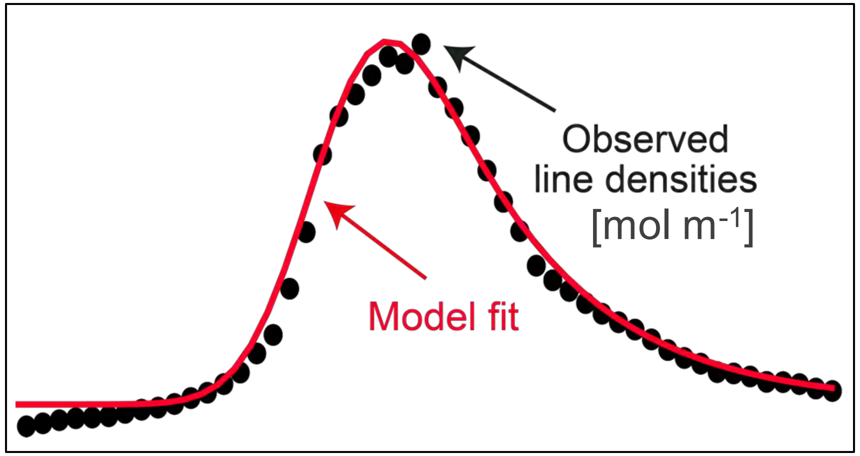
Derive NO_x emissions of isolated hotspots viewed by UV-visible space-based sensors

Rotate a hotspot using wind fields



Apply Gaussian function to wind-rotated plume

Across-wind sum of vertical columns



Use best-fit parameters to calculate emissions

25 mol NO_x s^{-1}

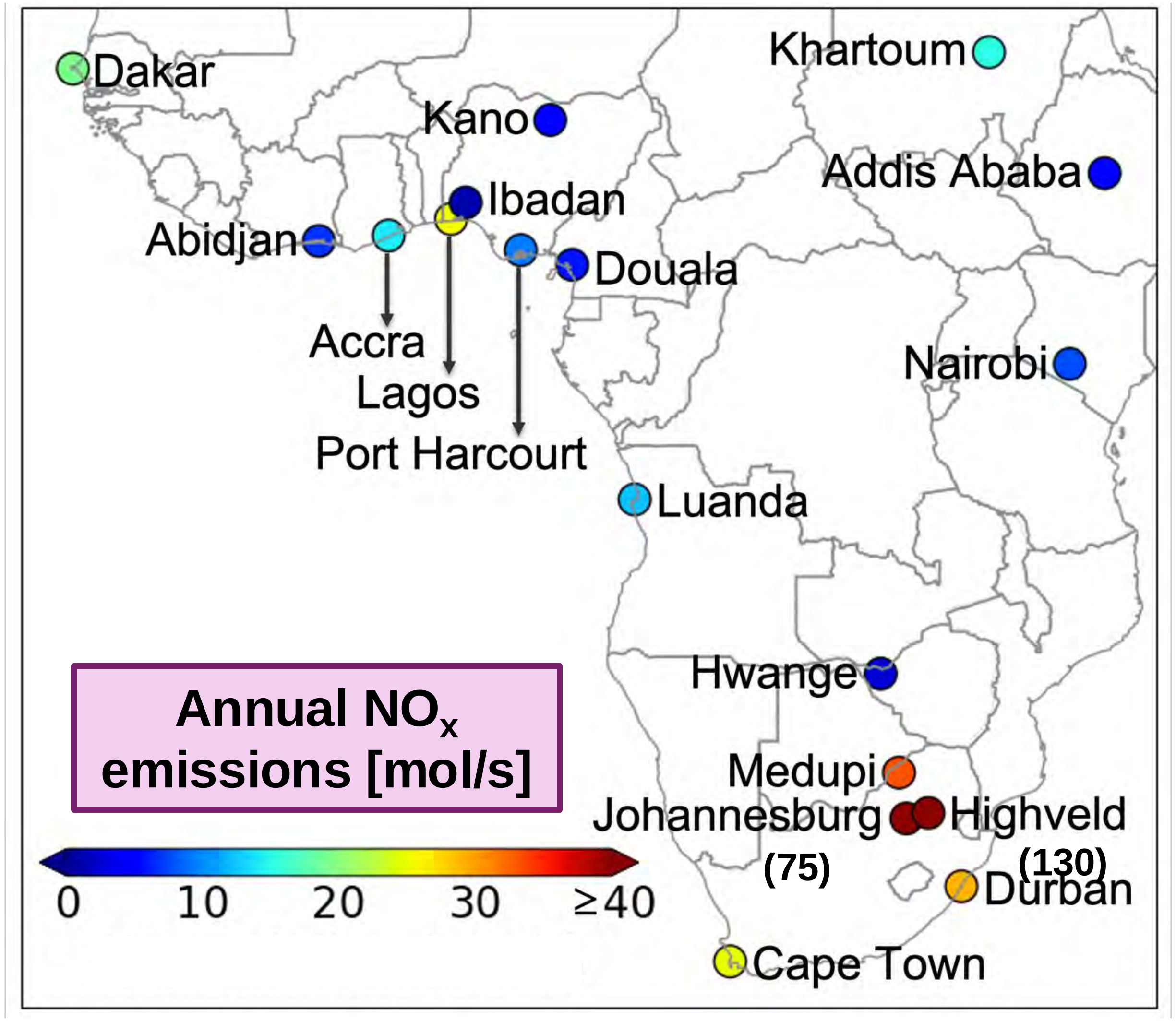
Obtain total NO_x emissions for the whole hotspot

Also applied to satellite observations of formaldehyde (HCHO) to calculate HCHO hotspot emissions

Point Source or Hotspot Emissions

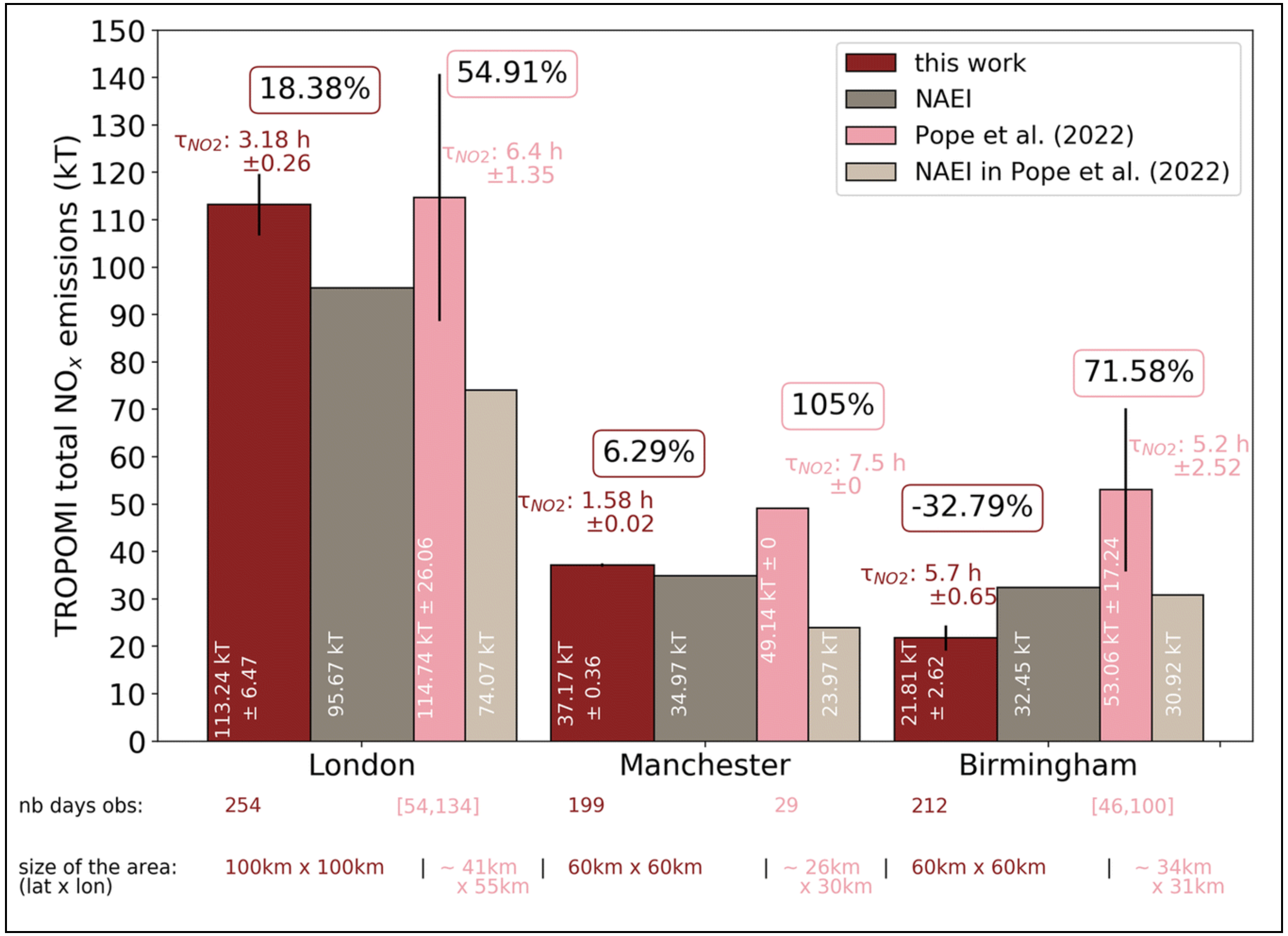
Example applications to cities, power plants and industrial areas in Sub-Saharan Africa and UK cities

Hotspots in Sub-Saharan Africa



Wei et al., *in prep*

UK Cities and Assessment of the NAEI

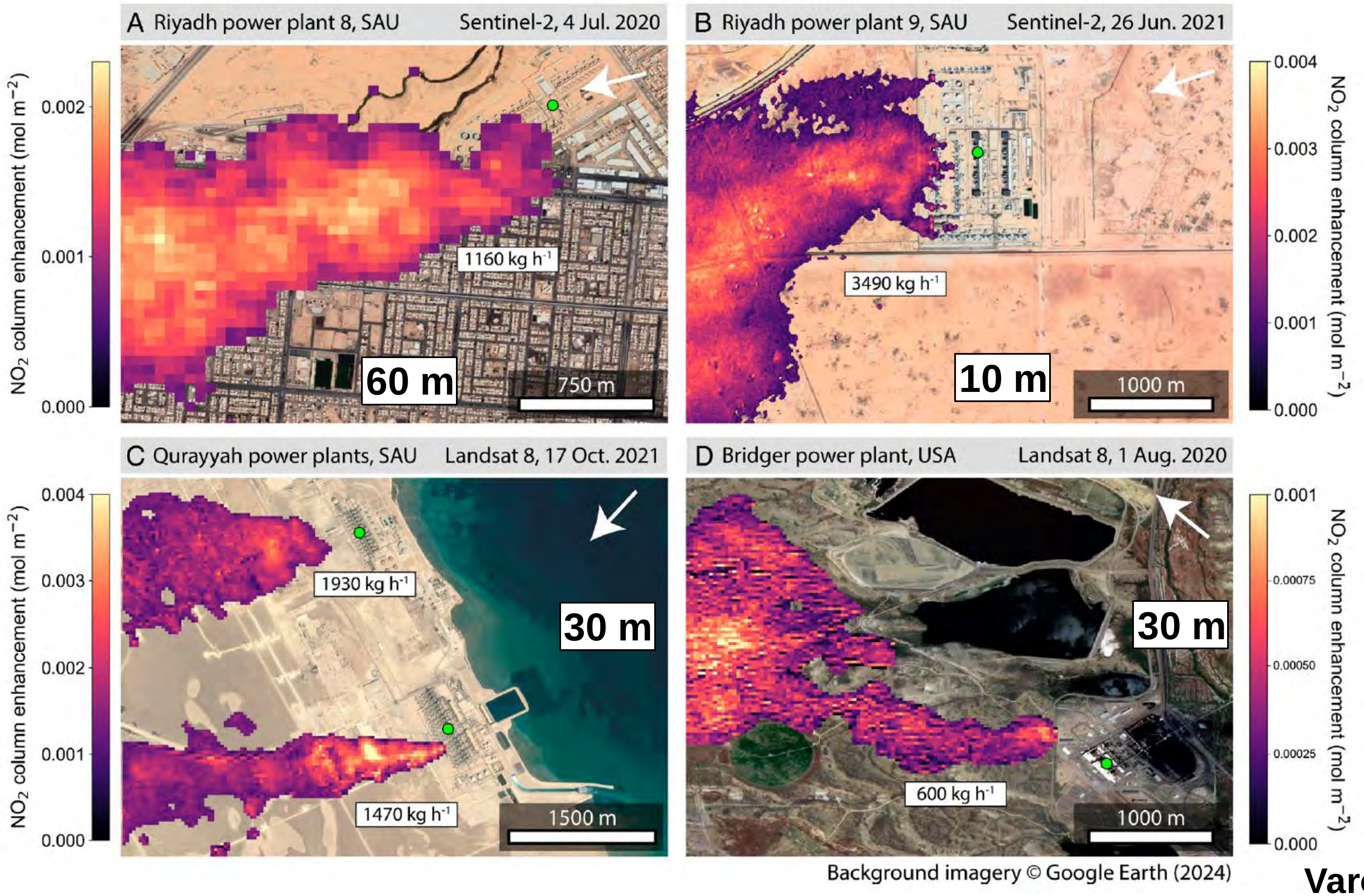


Pommier et al., ES: Atmos, 2023

Very High Spatial Resolution Emissions

NO_x emissions calculated from instruments designed to monitor terrestrial resources and land use

Progress from kilometre to <100 m scale

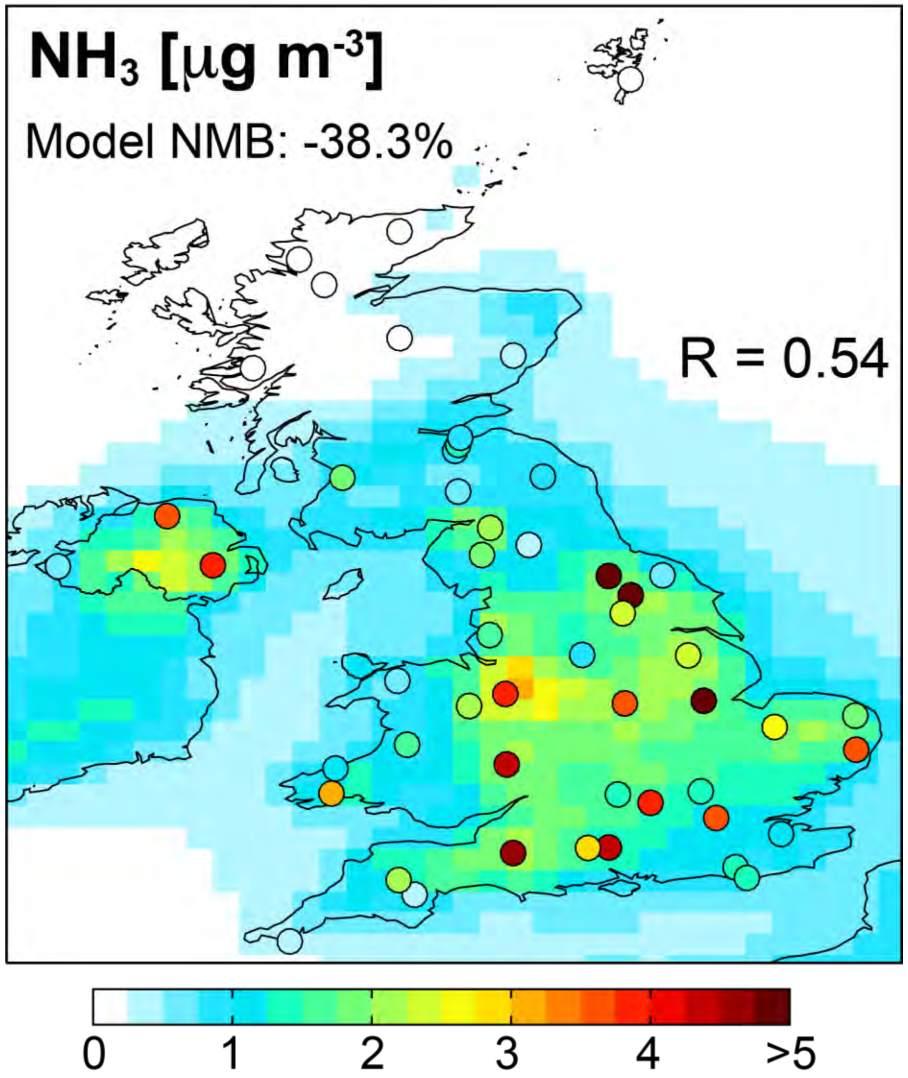


Varon et al., PNAS, 2024

Potential UK applications: industrial and energy (CHP) sources, urban congested roadways, airports

Ground-truthing Remains a Key Challenge!

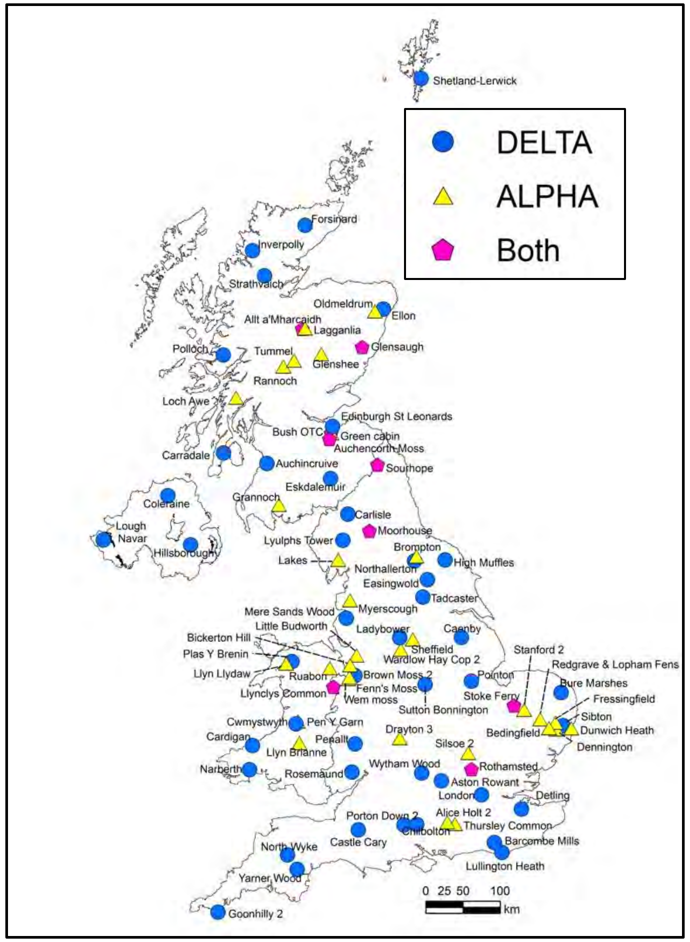
Network (points) and model (background) surface NH_3 in Mar-Sep



Points are for DELTA instruments (blue circles)

DELTA instruments support model underestimate (**NMB = -38%**)

So do passive low-cost ALPHA instruments (yellow triangles) (**NMB = -41.5%**)



GEOS-Chem underestimate in surface NH_3 driven with the NAEI corroborates results from IASI

Leads to reluctance to uptake by inventory developers and integration in policy decisions

In Summary

- Calculate area emissions for sources like agriculture and biogenic volatile organic compounds (specifically, isoprene)
- Achieve finer scales than native resolution of instrument with gridding techniques like oversampling
- Calculate point source or hotspot emissions by resolving the hotspot plume and fitting a Gaussian-type function
- Derive 10-60 m resolution emissions by retrieving air pollutant concentrations from land-surveying instruments
- Compare satellite-derived emissions to bottom-up (inventory) estimates to identify differences that should be investigated further
- Ground-truthing remains an issue to extent utility beyond research
- Lots of caveats and sources of uncertainty that will be covered in the next presentation by Dr Richard Pope

Links to Cited Peer-reviewed Studies

- Van Damme et al., ERL, 2021: https://iopscience.iop.org/article/10.1088/1748-9326/abd5e0
- Marais et al., JGR, 2021: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JD035237
- Hellsten et al., 2008: https://doi.org/10.1016/j.envpol.2008.02.017
- Pommier et al., 2023: https://pubs.rsc.org/en/content/articlelanding/2023/ea/d2ea00086e
- Varon et al., 2024: https://www.pnas.org/doi/10.1073/pnas.2317077121