Top-down estimates of ammonia (NH_3) emissions to characterise the influence on local air quality

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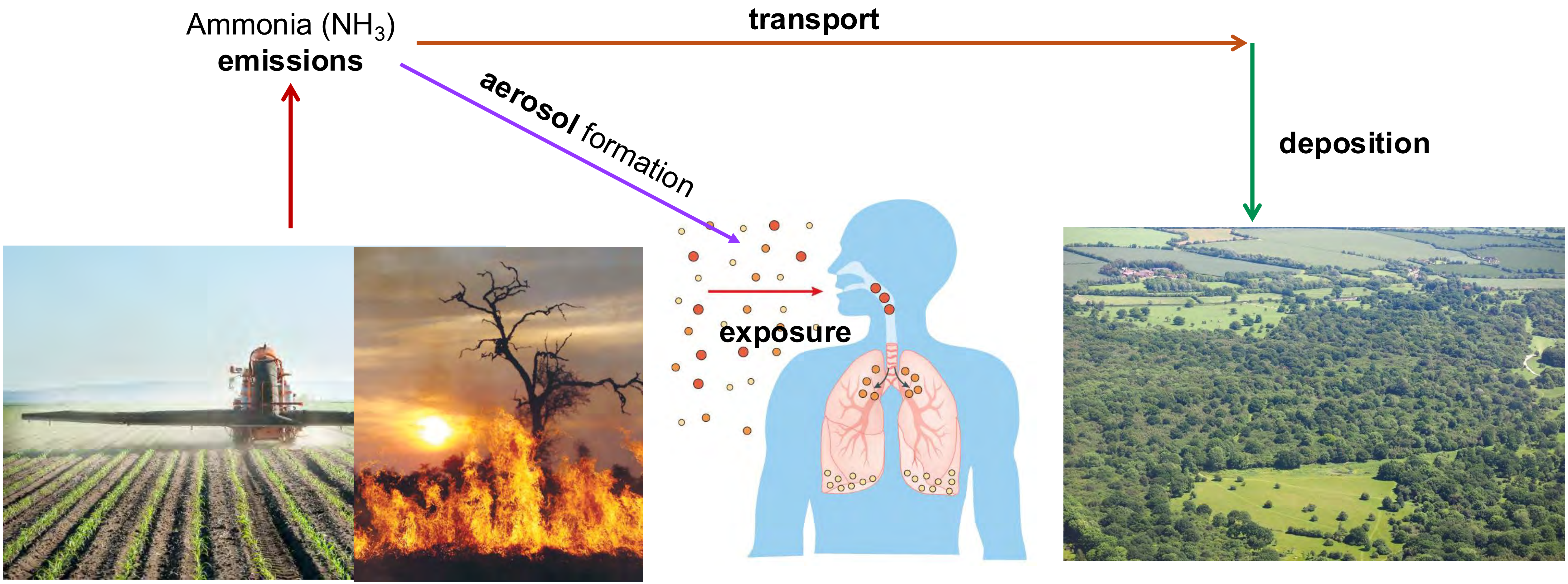
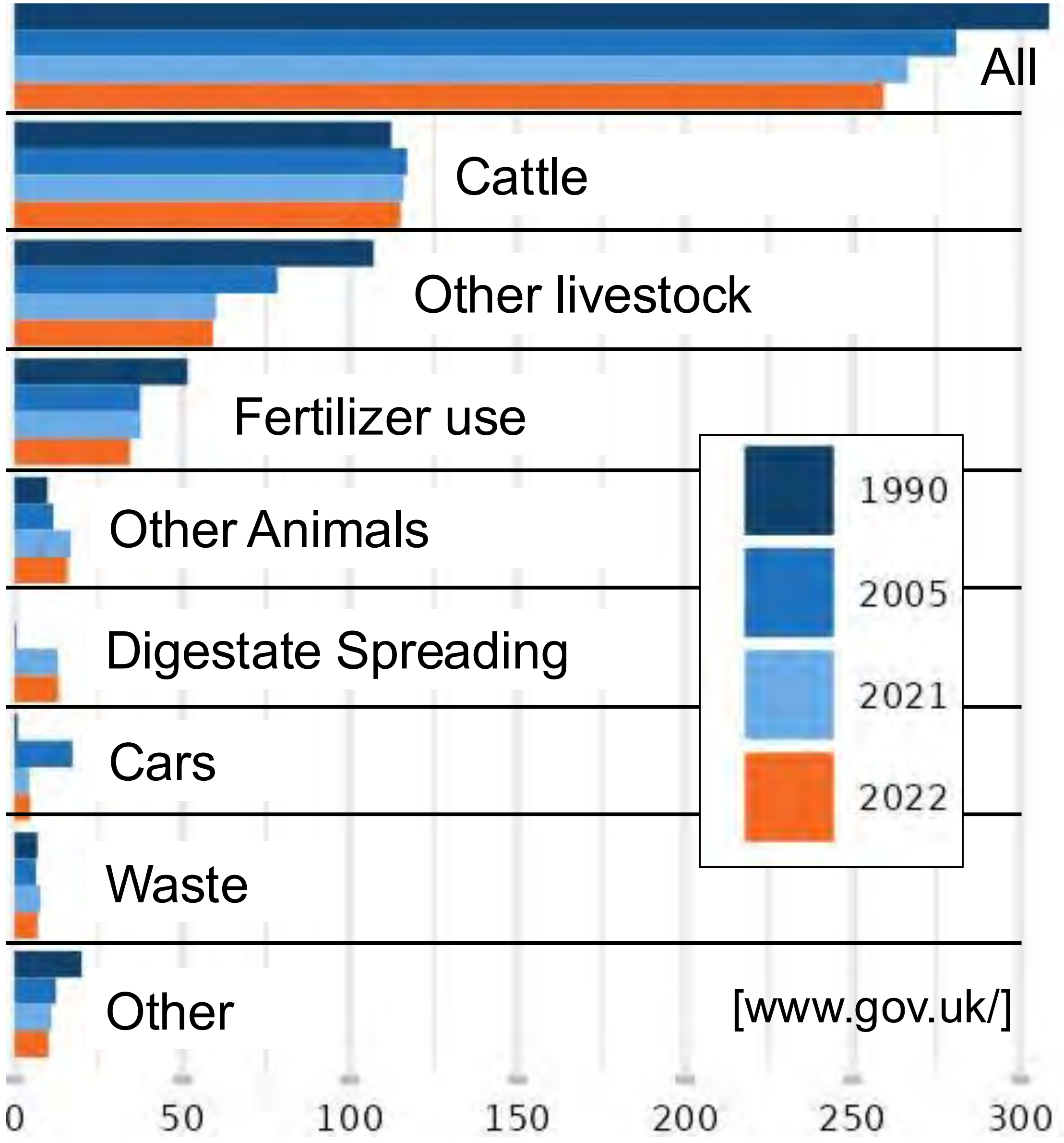
Agricultural and fire emissions of ammonia affect air quality, human health, and ecosystem vitality



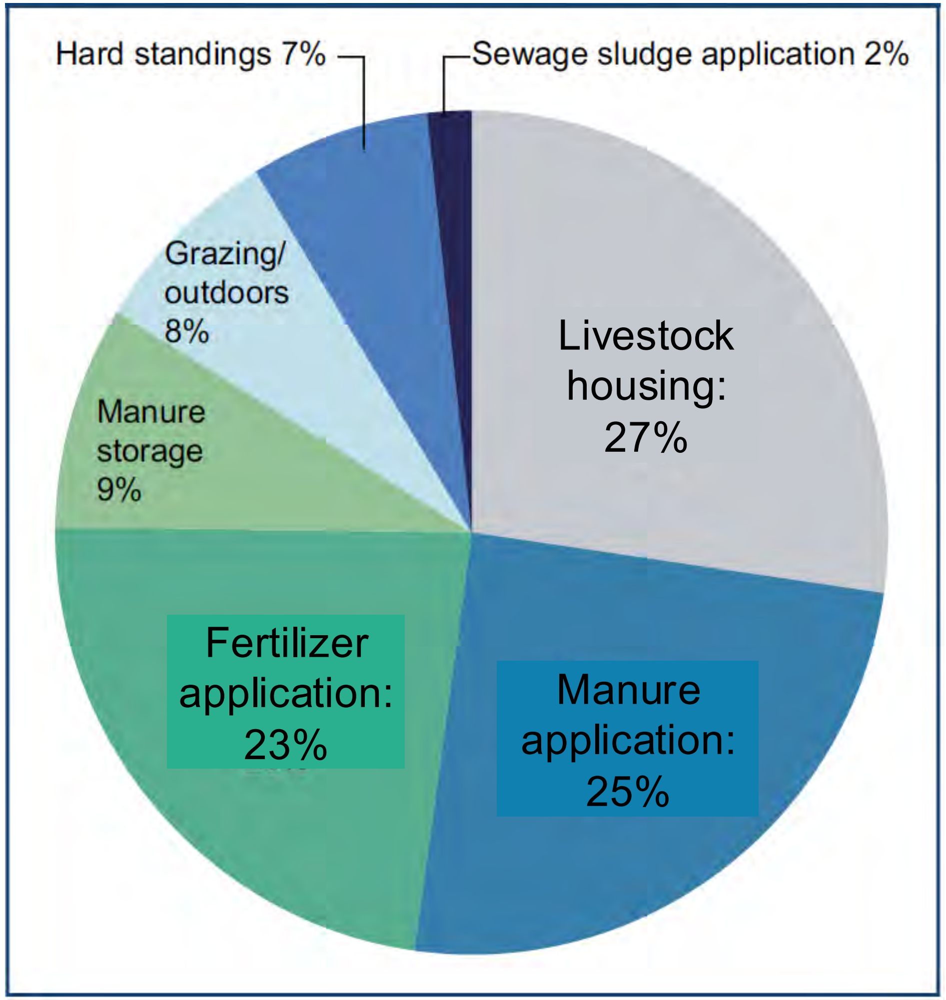
Ammonia is a precursor of fine particles and deposit nitrogen to sensitive habitats

Ammonia Emissions from Agriculture

UK NH_3 Emissions [thousands tonnes]



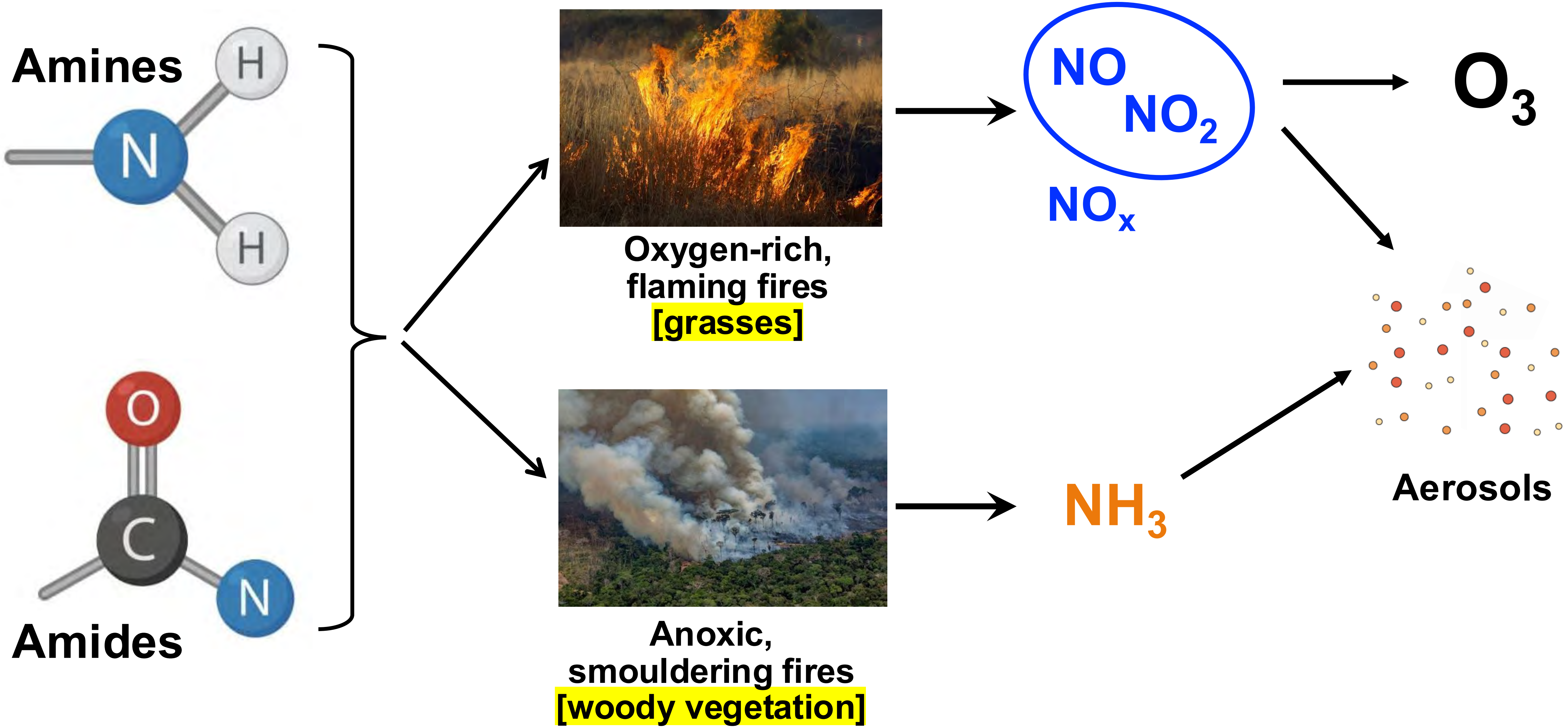
Contribution of management practices



[UK Clean Air Strategy, 2019]

>80% of total NH_3 emissions in the UK

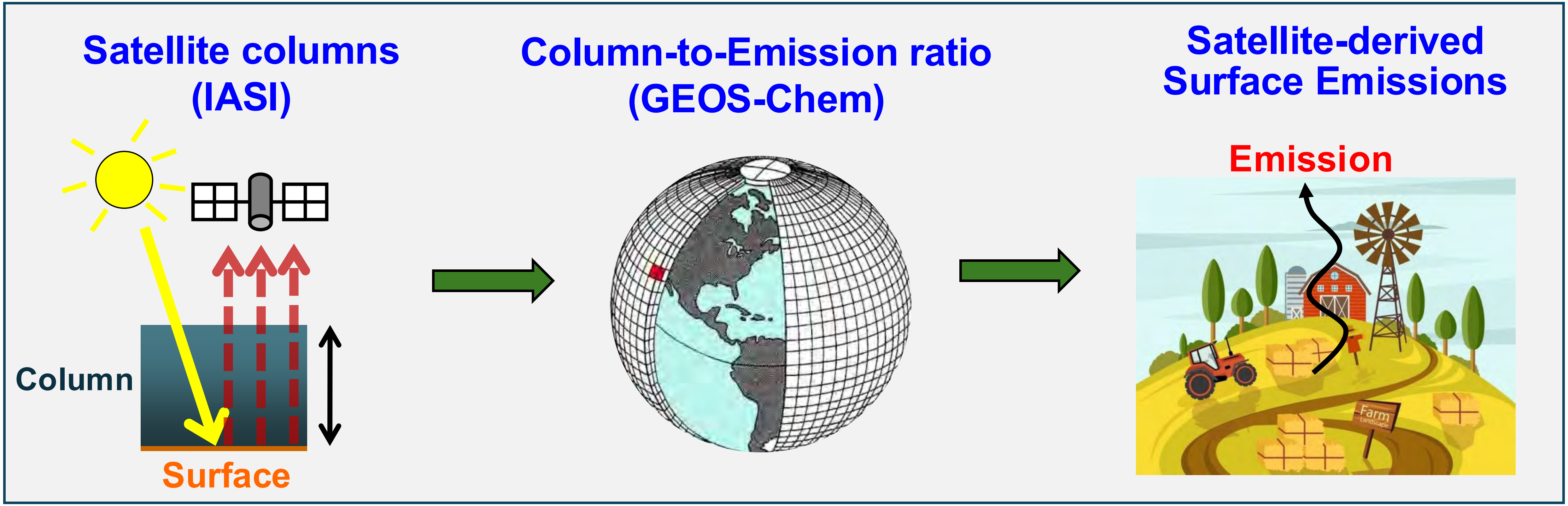
Ammonia Emissions from Burning Biomass



Observationally-derived (Top-Down) NH_3 Emissions

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

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

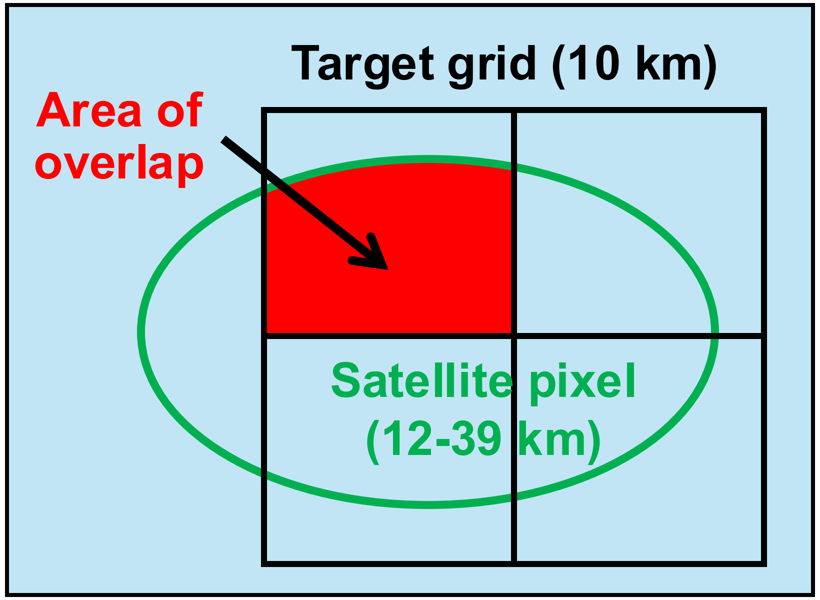


Simple mass-balance inversion method made possible by relatively short NH_3 lifetime

Preprocess IASI to Finer Resolution Grid than Instrument

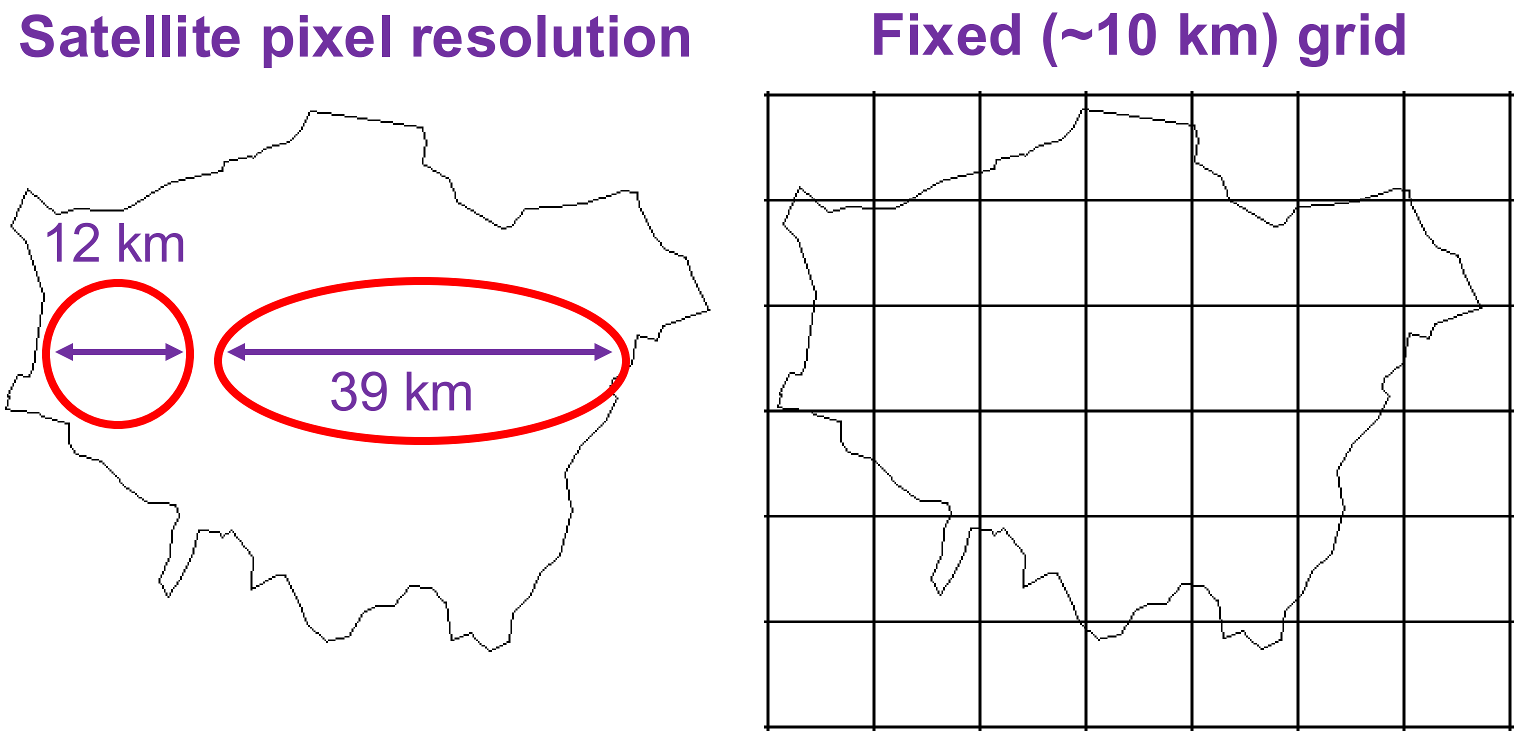
Use so-called oversampling to enhance spatial resolution relative to native resolution of instrument

Oversampling Technique



Weights pixel by area of overlap

Oversampling technique over London

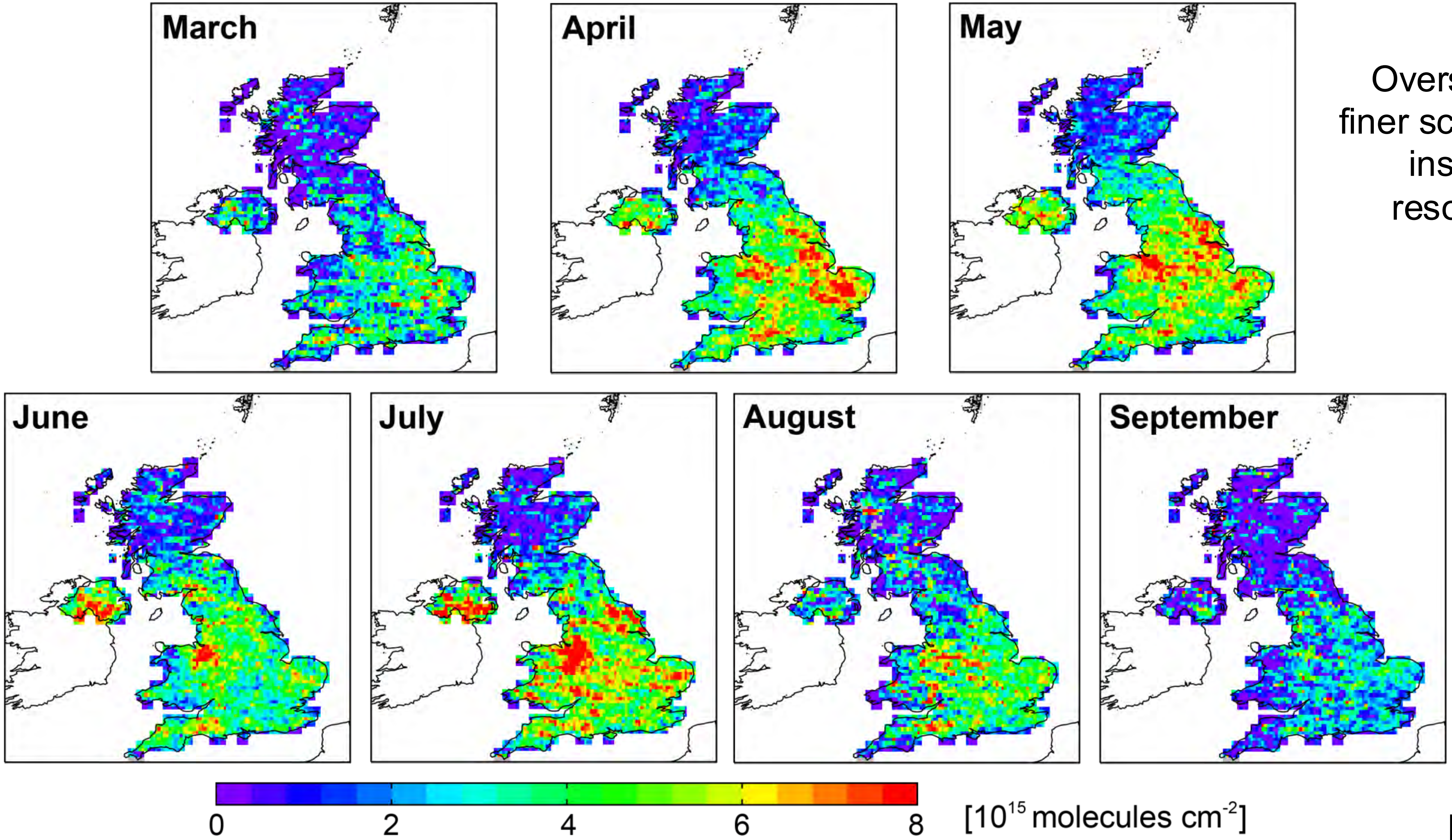


Lose time (temporal) resolution; gain spatial resolution

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

Multiyear means from the IASI version 3 ammonia

Multiyear (2008-2018) monthly means for warmer months of the year



Oversampling used to finer scales (~10 km) than instrument native resolution (~12 km)

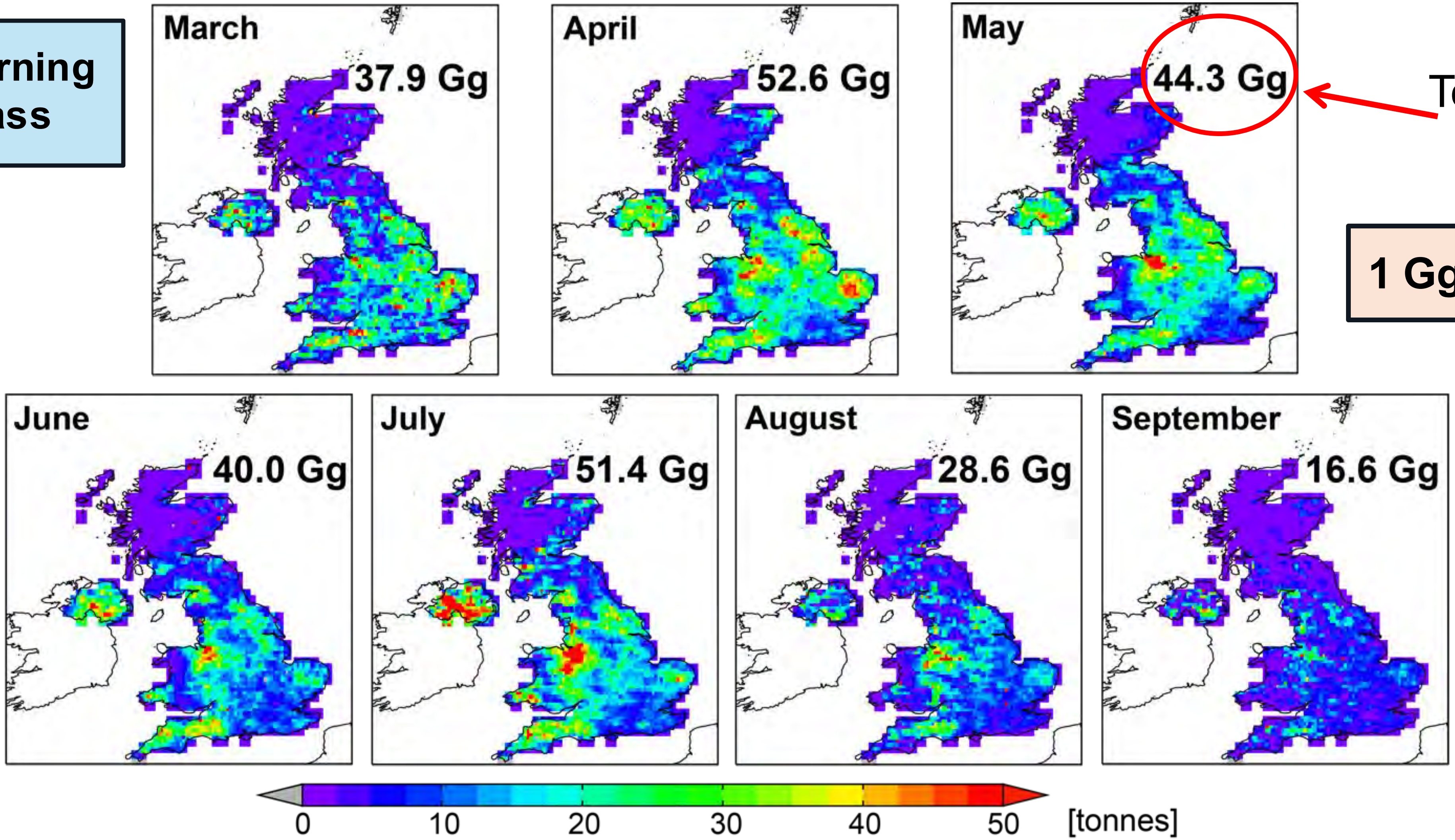
[Marais et al., 2021]

Climatological mean to be consistent with bottom-up ammonia emissions

IASI-derived multiyear (2008-2018) monthly mean NH_3 emissions

Focus on **Mar-Sep** when warm temperatures and clearer conditions increase sensitivity to surface NH_3

IASI: morning overpass



Total monthly emissions

1 Gg = 1 kilotonne

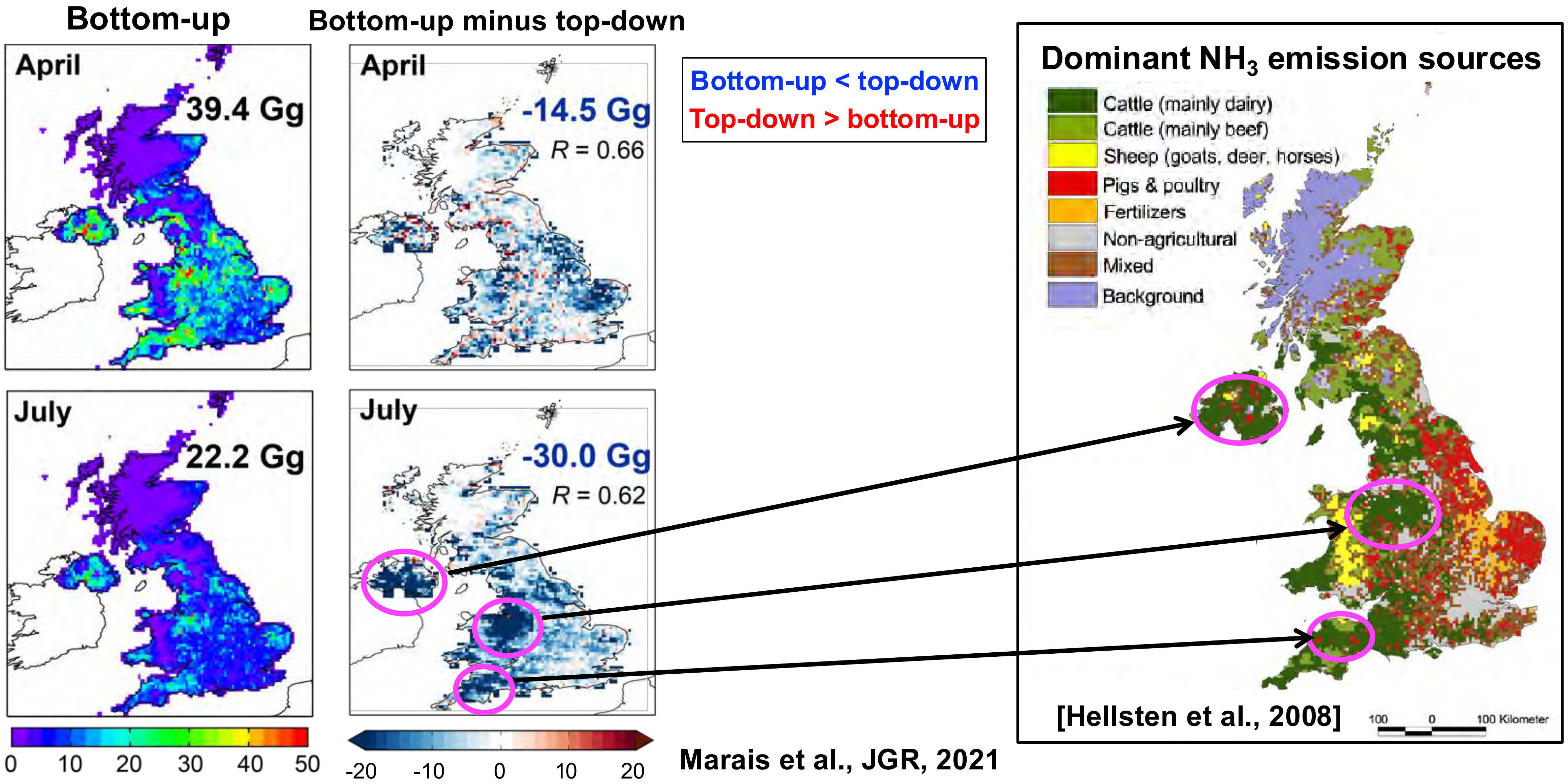
[Marais et al., 2021]

Monthly emissions for March-September from **IASI**-derived estimates sum to **271.5 Gg**

Uncertainty range is 11-36% and bottom-up is ~27% less than IASI-derived emissions

Satellite vs inventory NH_3 emissions: spatial distribution

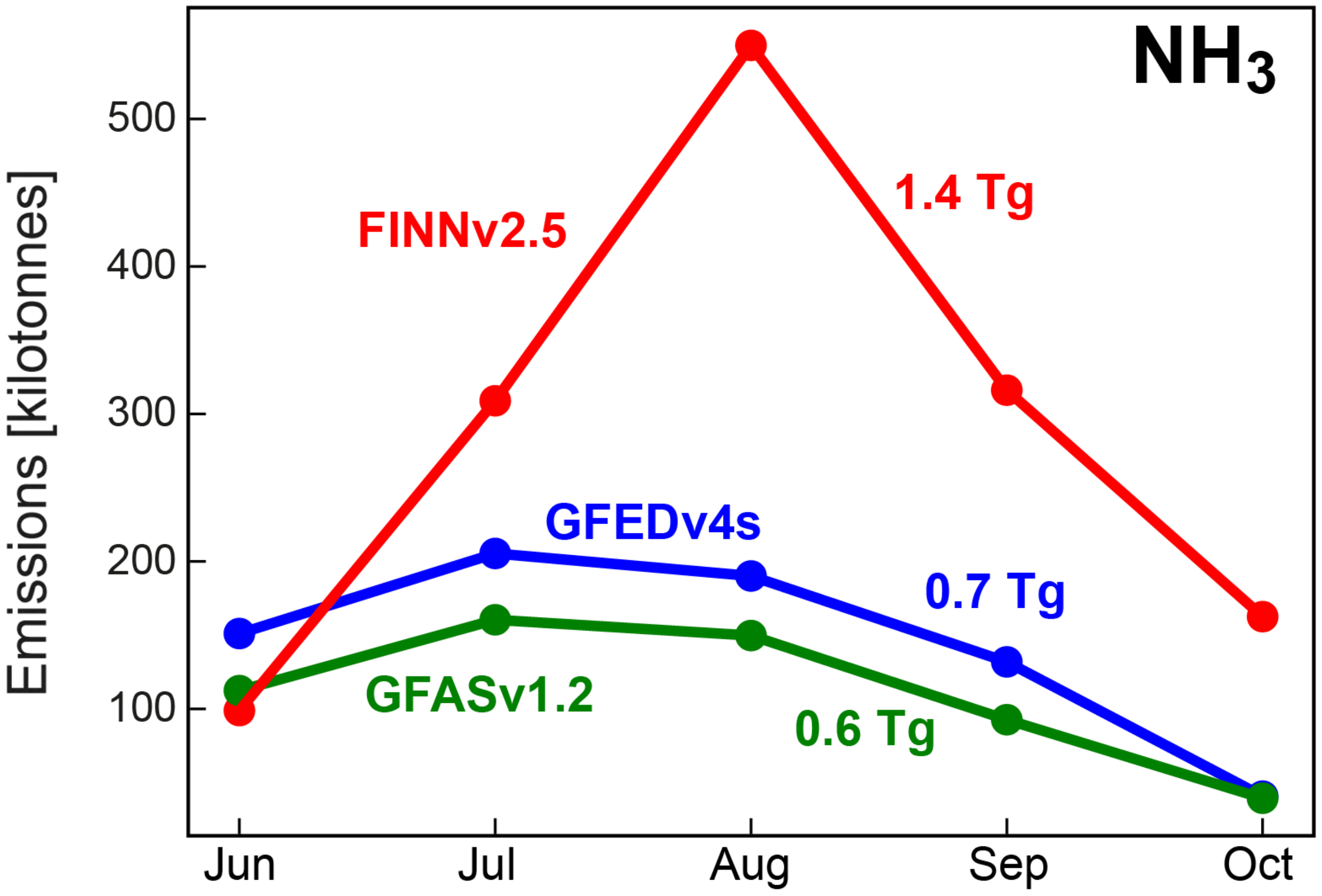
Comparison of months with peak emissions according to IASI (April and July)



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

Biomass Burning Ammonia Emissions in Southern Africa

Monthly bottom-up June-October 2019 emissions



MODIS Landcover

Inventory differences:

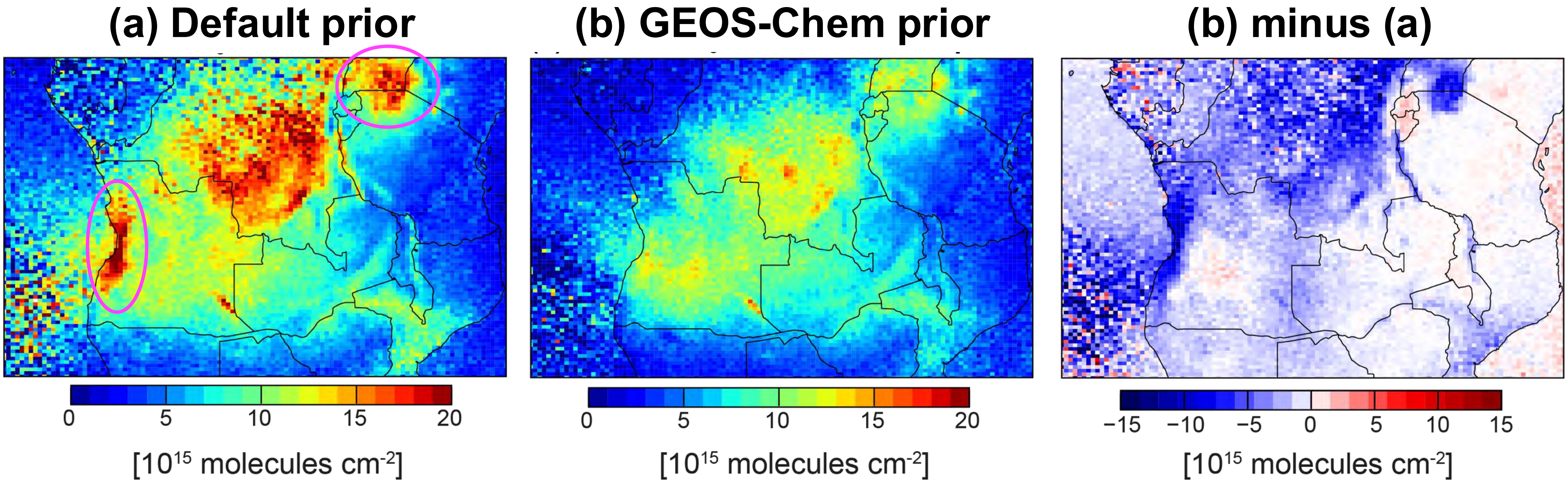
- Emission factors
- Fire data
- Time resolution
- Spatial resolution
- Injection height
- Small fires
- Landcover classes

Mostly savanna fires. Some tropical forest fires.

Apply all 3 inventories GEOS-Chem to compare to IASI for NH_3

Reprocess IASI version 4 with local GEOS-Chem priors

IASI columns for July-October 2019. Prior from GEOS-Chem with FINN emissions



Overall decline in columns with local a priori, as more NH_3 placed higher up

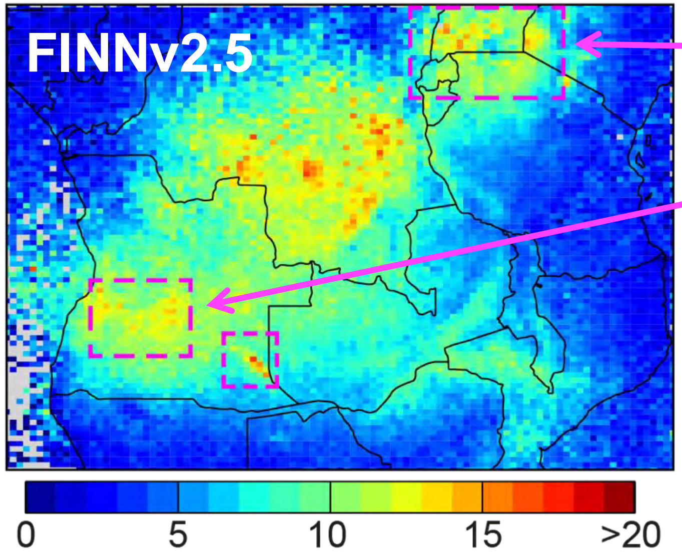
Less noisy over Atlantic Ocean east of Angola and northern Namibia

More retrievals pass quality checks

Evaluation of Inventories with Satellite Observations

NH_3 vertical column densities for Jul-Oct 2019 [10^{15} molecules cm^{-2}]

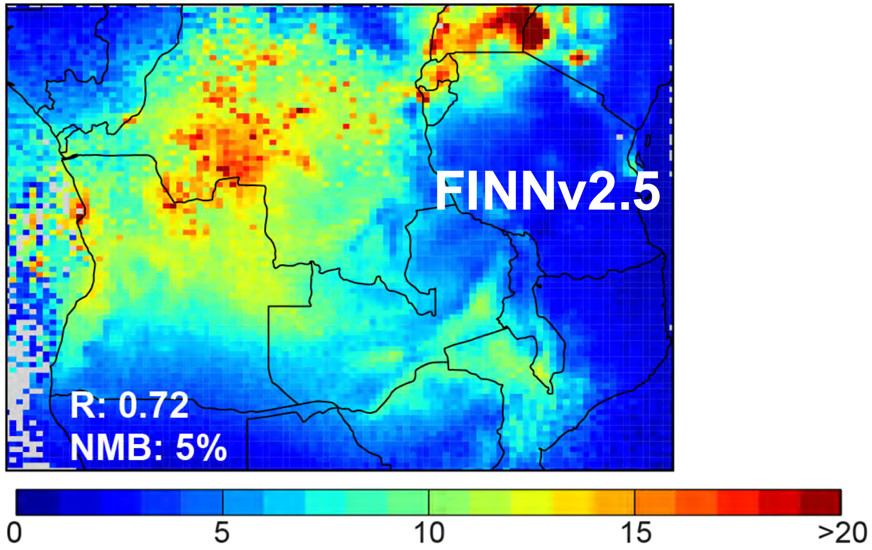
IASI with GEOS-Chem prior:

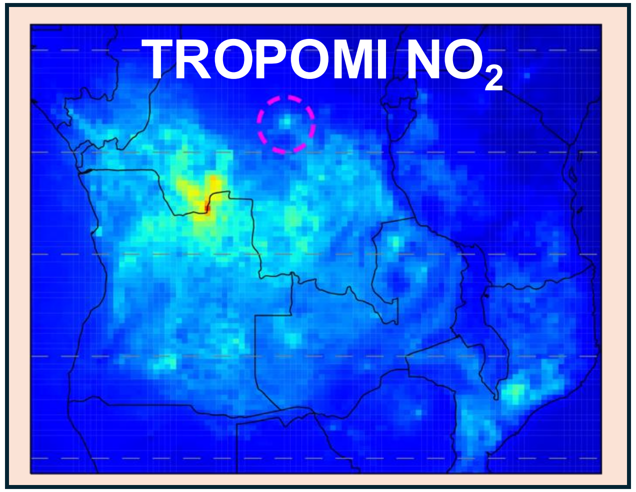


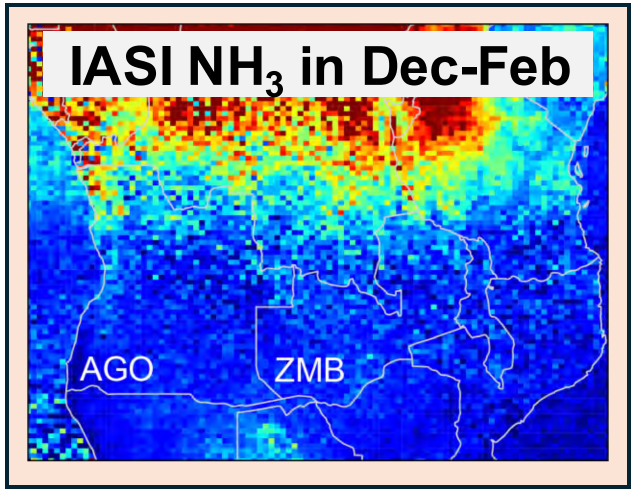
Anthropogenic NH_3 in the Lake Ukerewe Basin

Fire NH_3 in Angola that no inventory reproduces

GEOS-Chem:







June excluded, as no inventories consistent with IASI observations (R < 0.5)

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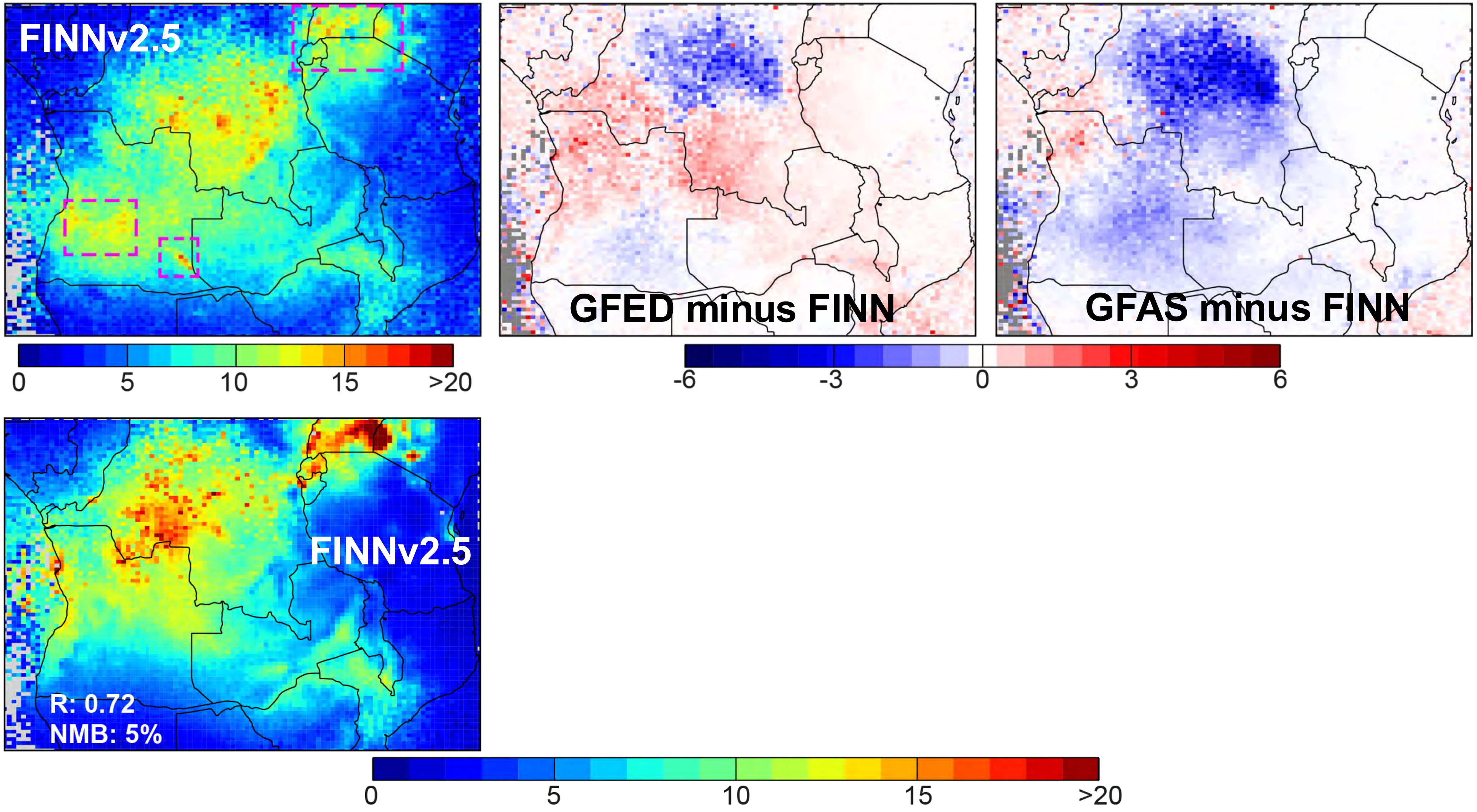
IASI with GEOS-Chem prior:

GEOS-Chem:



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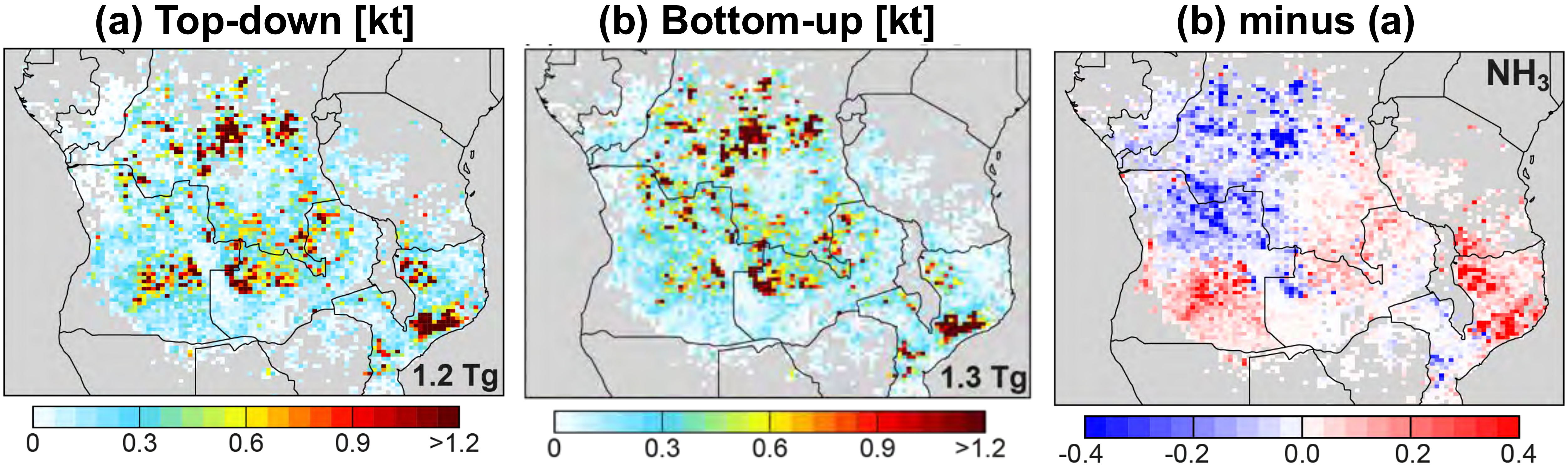
Top-down Emissions with Best Performing Inventories

Calculate emissions for GEOS-Chem gridsquares with > 50% biomass burning emissions



Uses GEOS-Chem driven with FINN inventory, as yields best agreement with IASI

Emissions long-tailed distribution and degrades correlation with NO_x emissions from $R > 0.8$ to $R < 0.4$

Emissions peak in August, just like inventory. Error estimate on emissions is 1.2±0.4 Tg.

In Summary

- Spatial resolutions of ~12-14 km enhanced by oversampling for UK NH_3, but lots of data needed
- Estimate UK agricultural emissions that are consistent with spring fertilizer location and timing
- Identify large bottom-up and top-down UK agricultural emissions discrepancies in summer over cattle farming intensive regions to steer further research
- FINN inventory better than GFED and GFAS at representing smouldering emissions of NH_3
- Suggests would outperform other inventories for other smouldering pollutants (VOCs, CO, organic aerosols, methane)
- Inventories collocate NH_3 and NO_x emissions (smouldering and flaming fires), but these are mostly separate in top-down estimates
- Need independent observations for biomass burning in Africa. Ideally in National Parks
- Geostationary infrared instrument soon to launch over Europe to observe NH_3 every 30 min (including over Africa) offers tremendous opportunity to advance top-down estimates further
- UK NH_3 paper: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JD035237
- Southern Africa NH_3 work in review.