Observation-based estimates of non-CO_2 greenhouse gases

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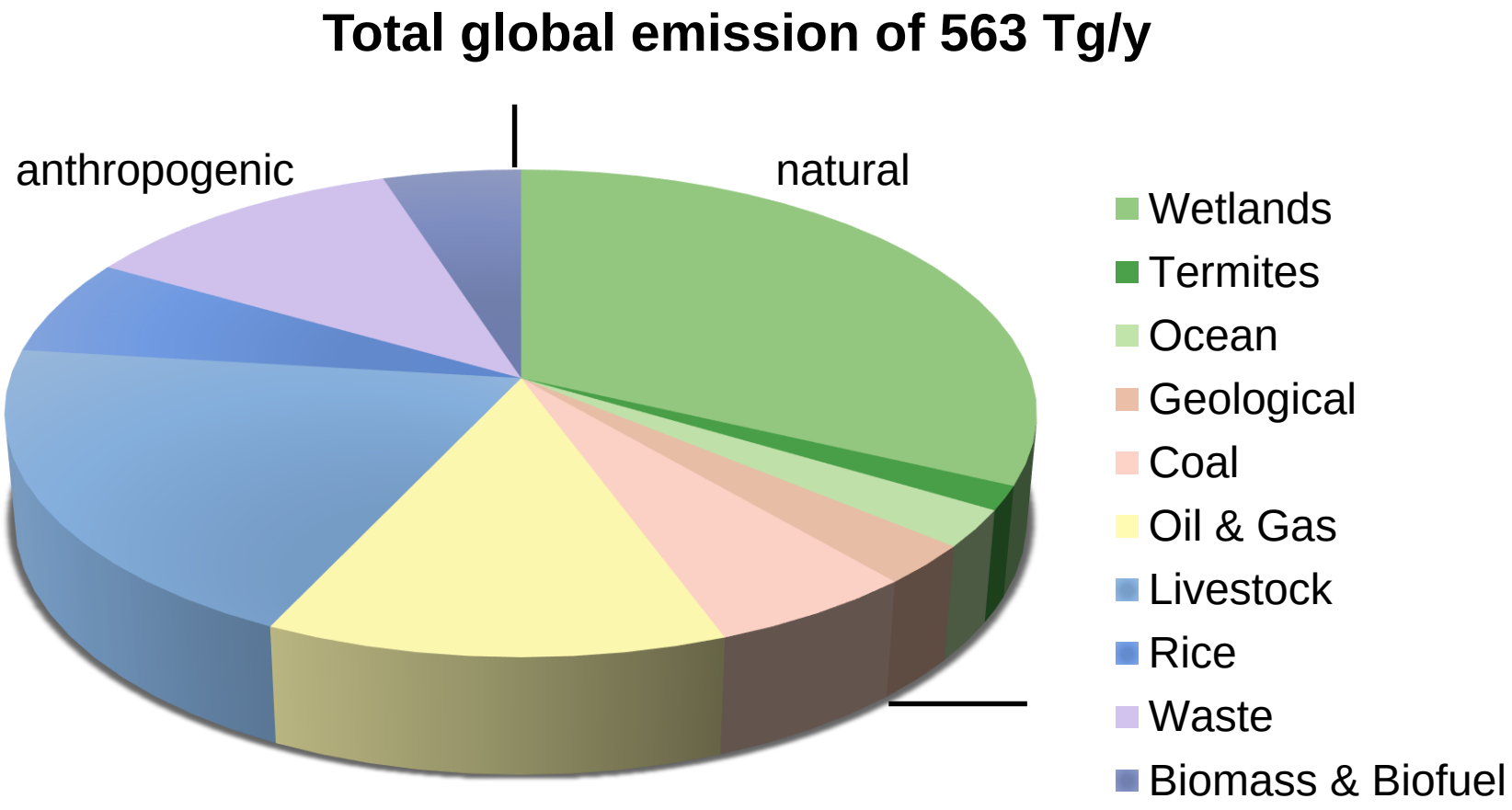
General Objectives

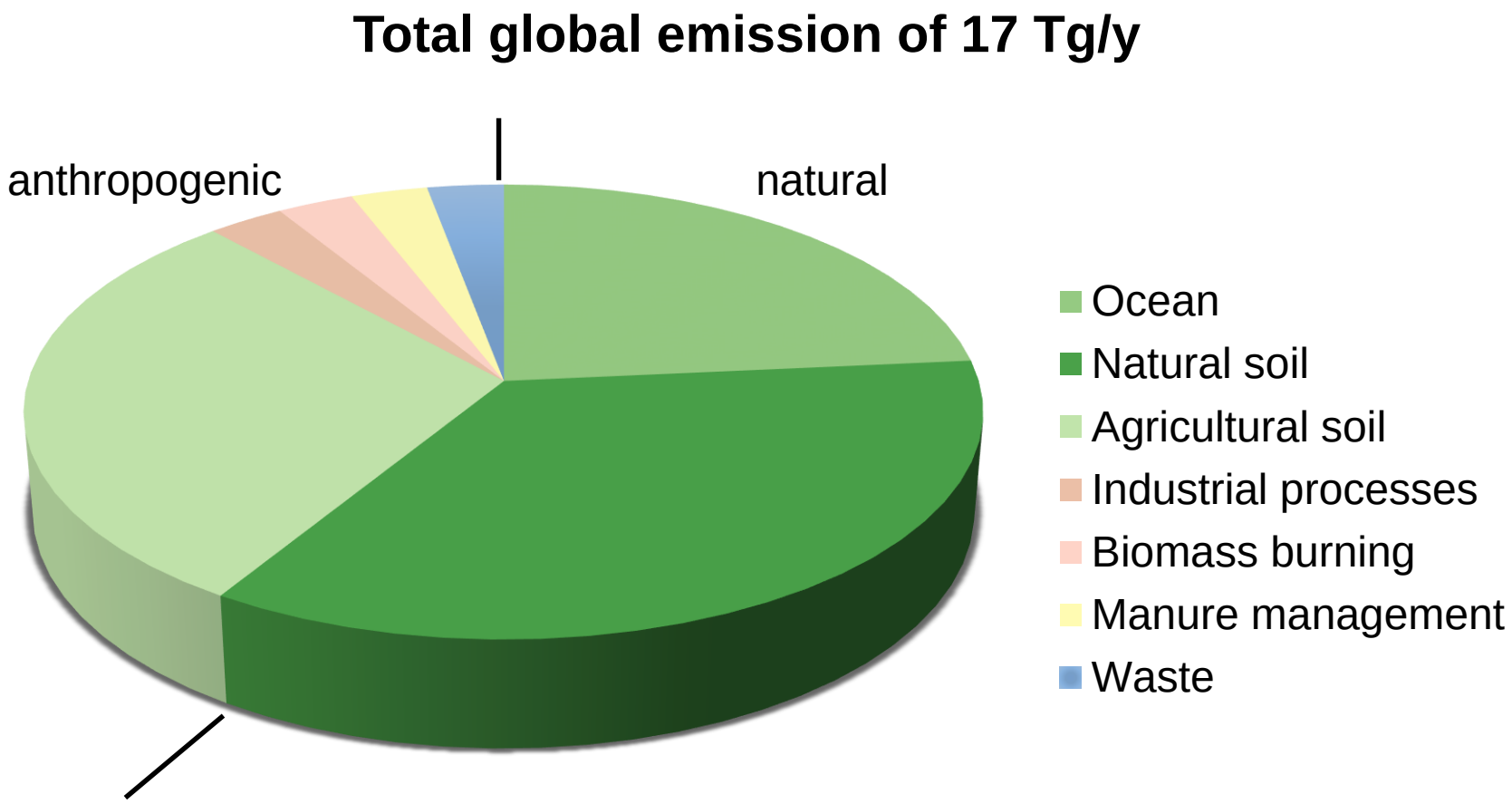
- Deliver estimates of CH_4 and N_2O fluxes, including anthropogenic as well as natural sources, and build this capacity into a pre-operational system
- Improve the understanding of the processes driving fluxes of CH_4 and N_2O, and **reduce the uncertainties in their budgets and trends** at national, regional and continental scales

Sources of methane



Data from the Global Carbon Project

Sources of nitrous oxide



Data from the Global Carbon Project

Uncertainties in BU estimates

Methane

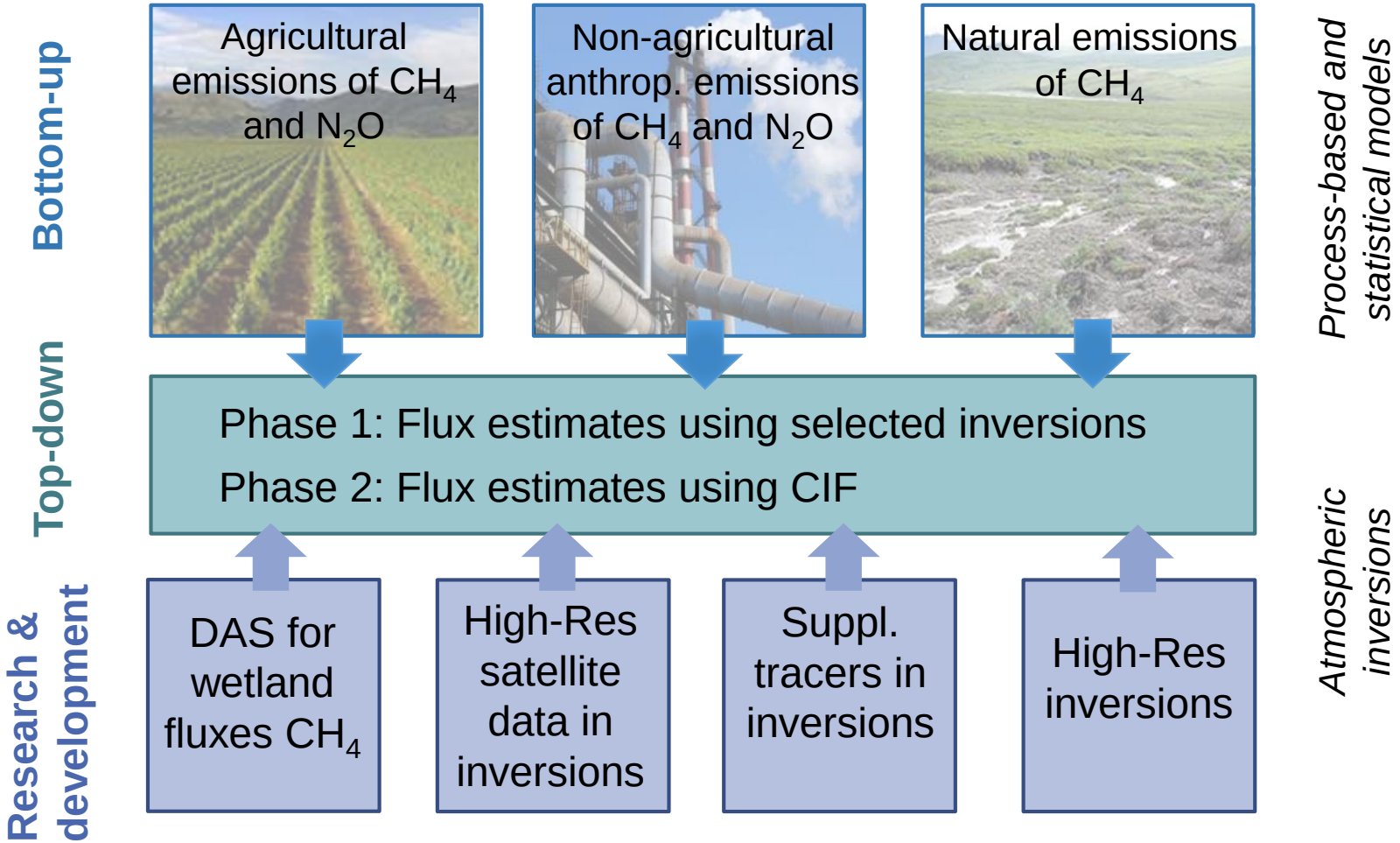
- Microbial emissions which depend strongly on local conditions (temperature, soil moisture etc.)
- Uncertainties on some sources >100%
- Challenging to represent with process-based models

Nitrous oxide

- Microbial emissions which depend strongly on local conditions (temperature, soil moisture etc.)
- Emission factor uncertainty range 30 to 300%
- Challenging to represent with process-based models

Large uncertainties in BU methods, therefore, likely that TD methods can contribute to improved estimates

Overview of the workflow



Bottom-up methods

for estimating CH_4 and N_2O emissions

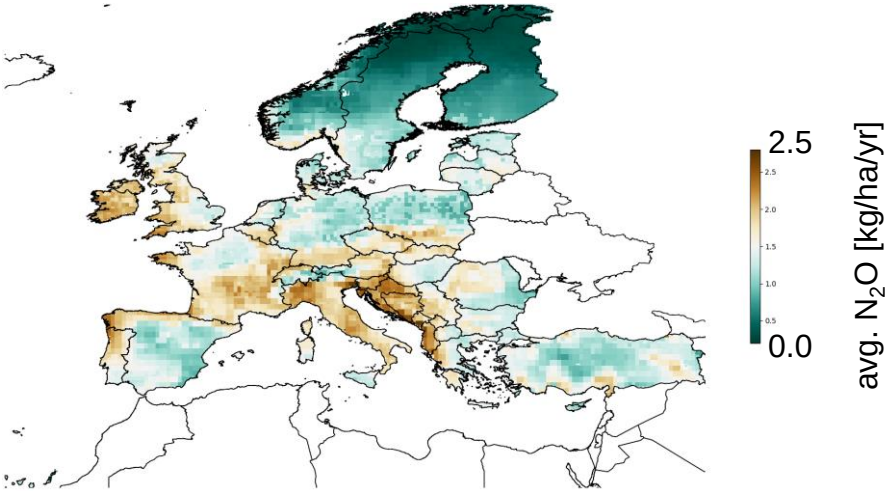
Agricultural emissions: methods

- Process-based model: ECOSSE
- Statistical model: CAPRI

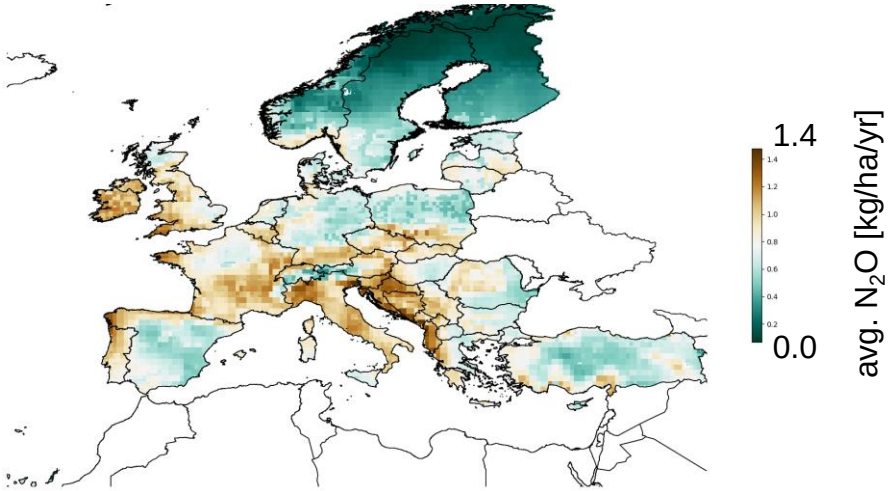
Sources	**Method/Model**	**Notable Inputs**
enteric fermentation (CH_4)	CAPRI based on IPCC Tier 1 approach (emission factors)	crop areas, yield, livestock densities, nutrient inputs
manure management (CH_4 + N_2O)		
direct + indirect emissions (CH_4 + N_2O)		
soil emissions (N_2O) (cropland, grassland, forests)	ECOSSE process-based land surface model	climate, land-use, nutrient inputs, & soil data

Agricultural emissions: N_2O

N_2O emissions for cropland (annual average 2005-2015)



N_2O emissions for grassland (annual average 2005-2015)



Preliminary results

Model approach is still under development

Problem:

Emissions in Central (e.g. NL) and Western Europe too low

Solution:

Fertilizer application needs to be changed from fertilizer demand to actual application rate

For grasslands:

In the actual assumptions management is not considered.

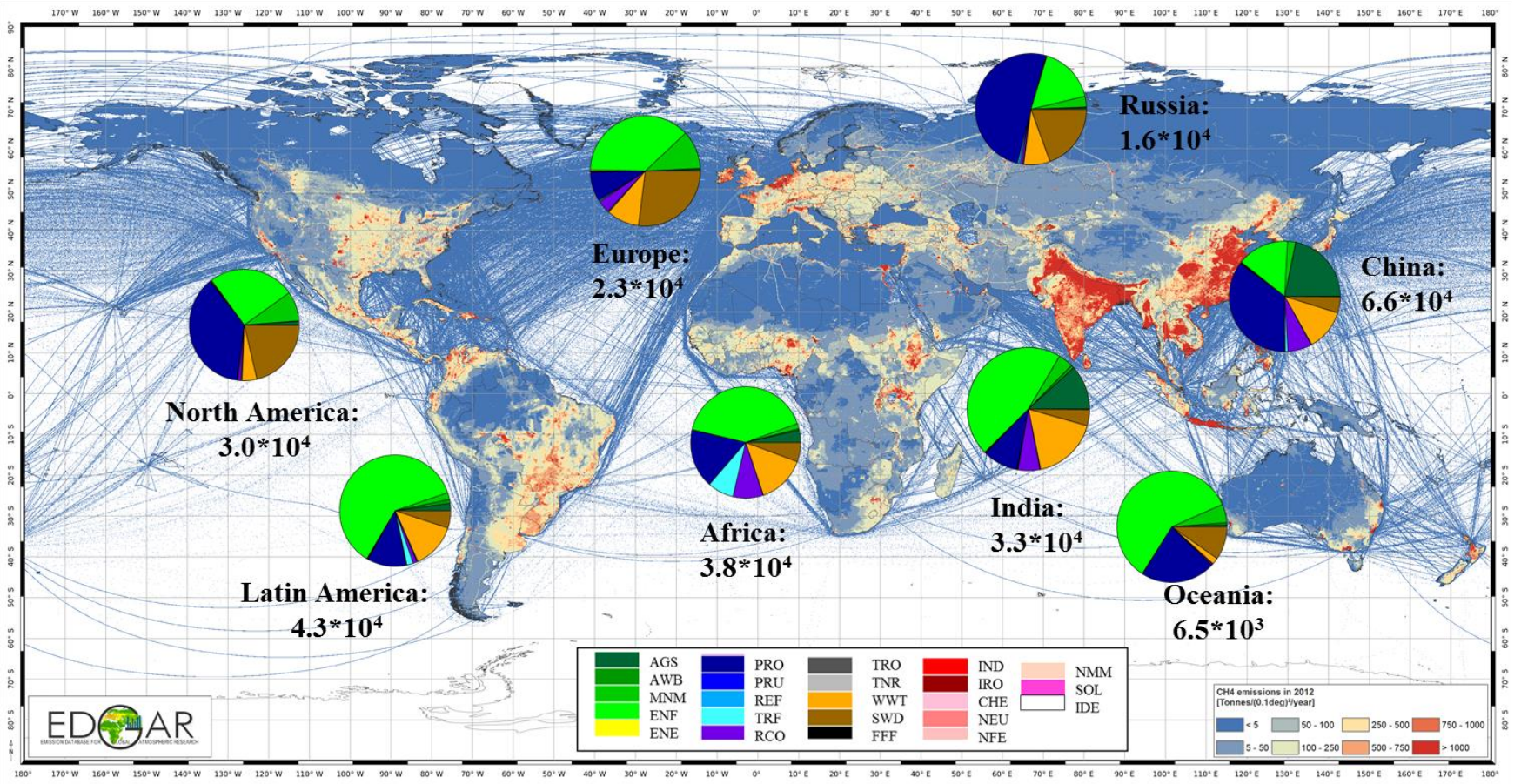
Other anthropogenic emissions

- EDGAR – Emission Database for Greenhouse Gas Research: uses activity data and IPCC Tier 1 approach. Estimates emissions for both agricultural and non-agricultural anthropogenic sources
- Used for both CH_4 and N_2O for **all countries**
- EDGAR final products: emission time series and global maps at 0.1°×0.1°

Sources (for VERIFY)	**Method/Model**	**Notable Inputs**
industrial	Based on EDGAR.v4.3.2 (1970-2012) and extended forward in time to 2015 (results expected 2019)	Activity data from international statistics and satellite remote sensing
residential		
transport		
energy		

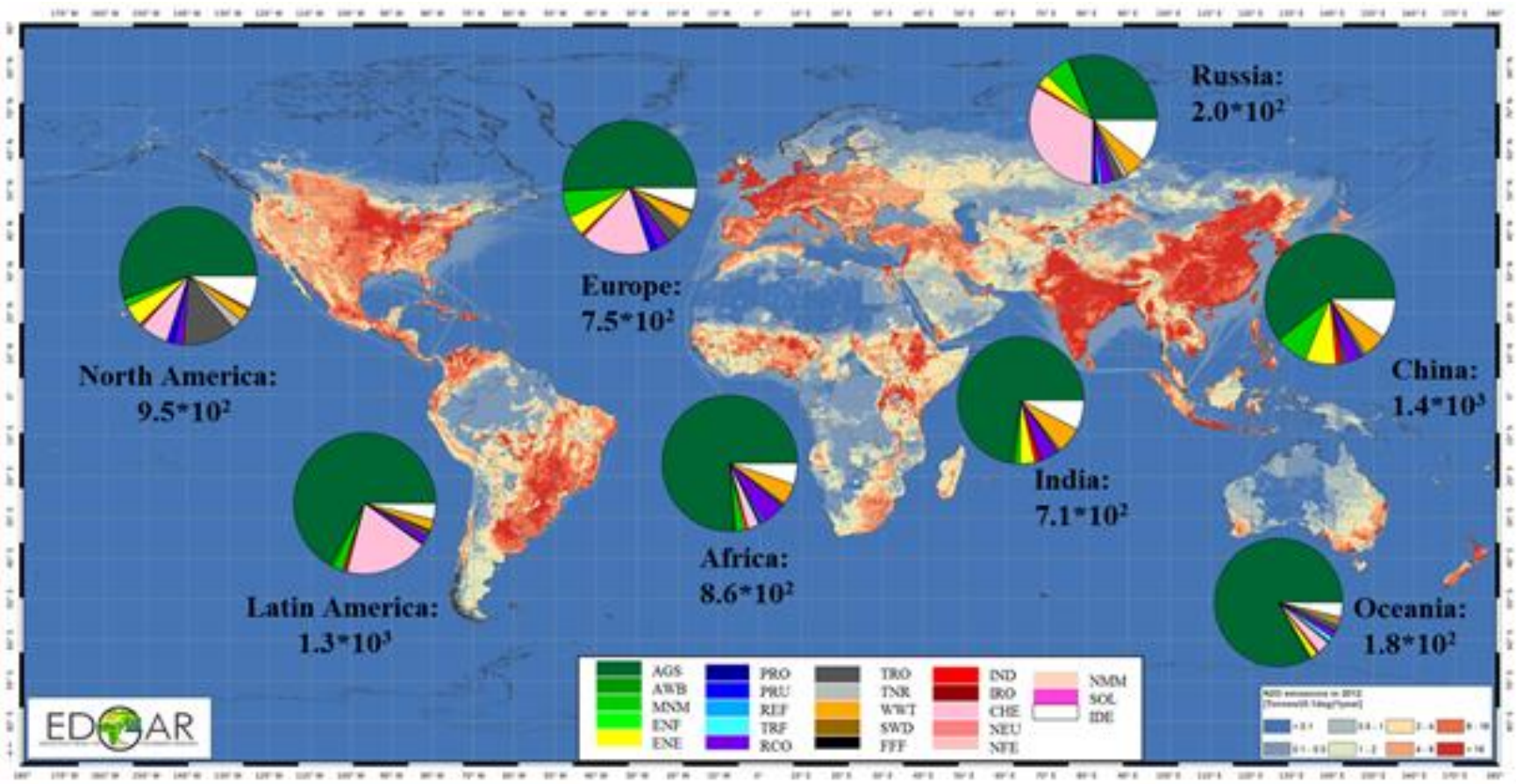
Other anthropogenic emissions

EDGARv4.3.2 CH_4

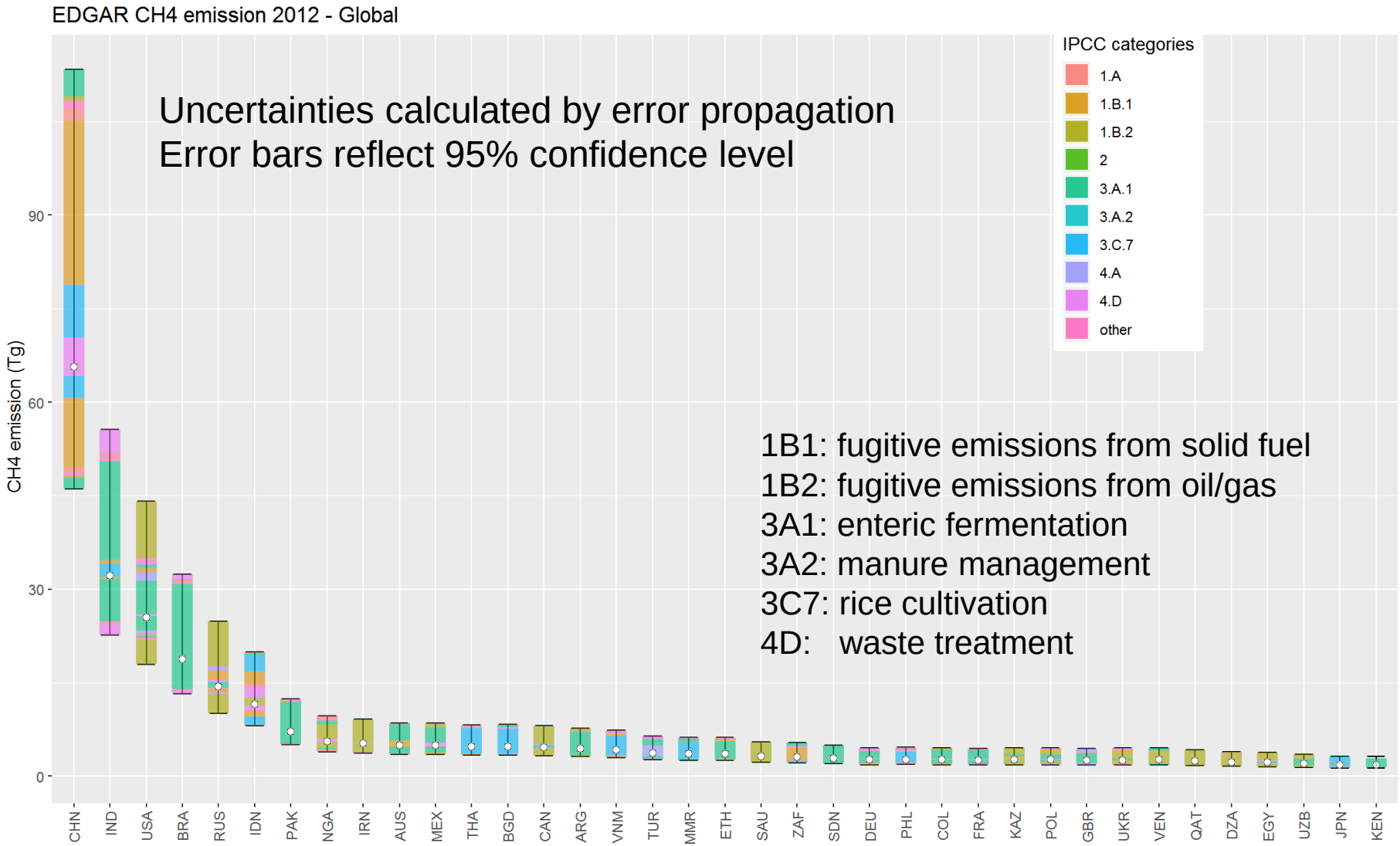


Other anthropogenic emissions

EDGARv4.3.2 N_2O



Other anthropogenic emissions



Soil and peatland emissions

JSBACH-YASSO-HIMMELI models

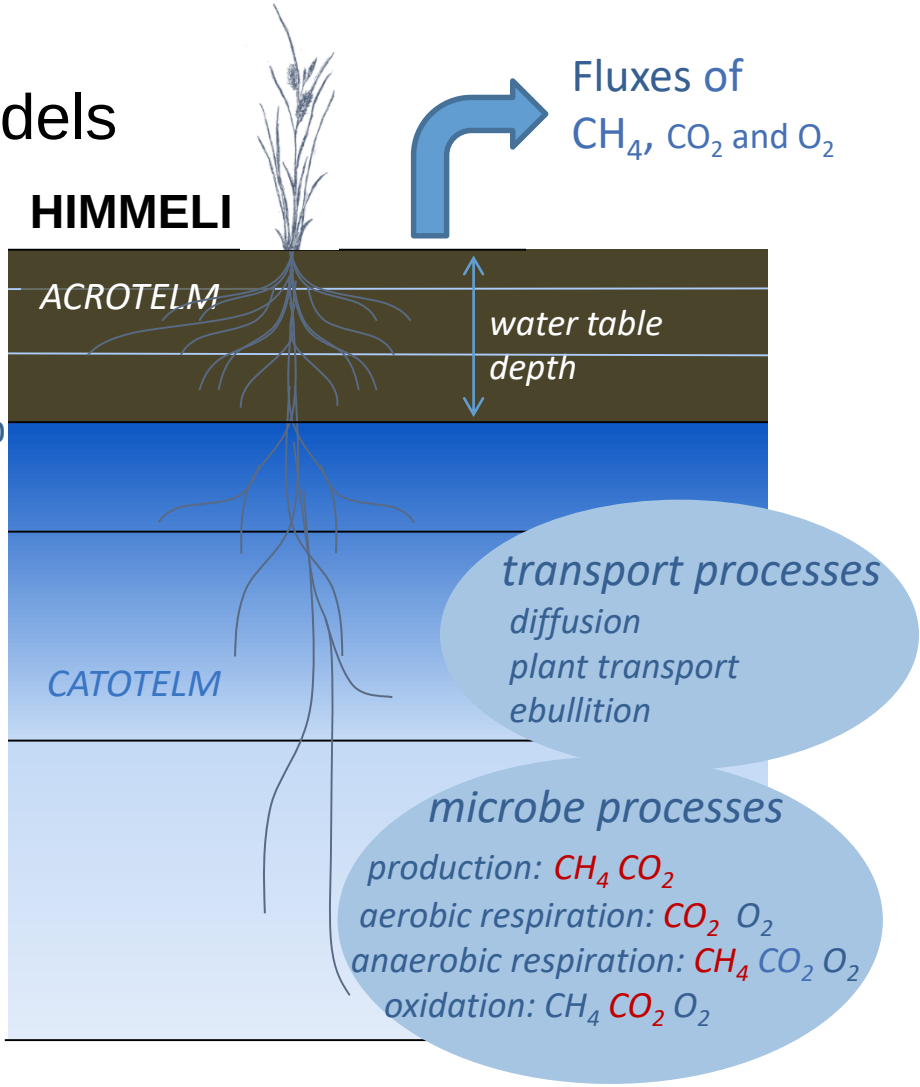
CRU-JRA climate data 0.5°×0.5° resolution

Temp, Prec, Rad

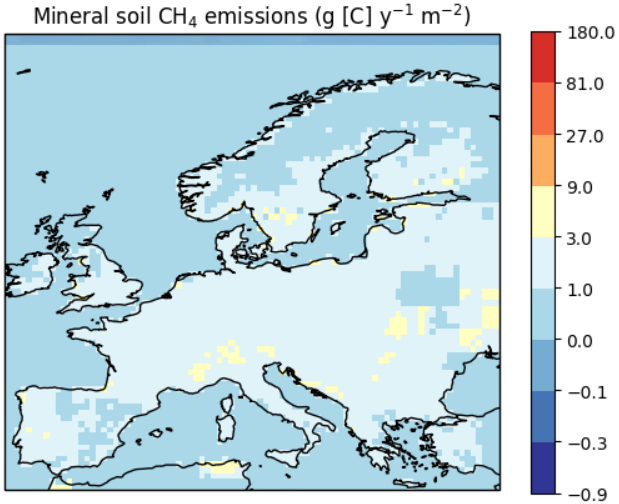
JSBACH land surface model

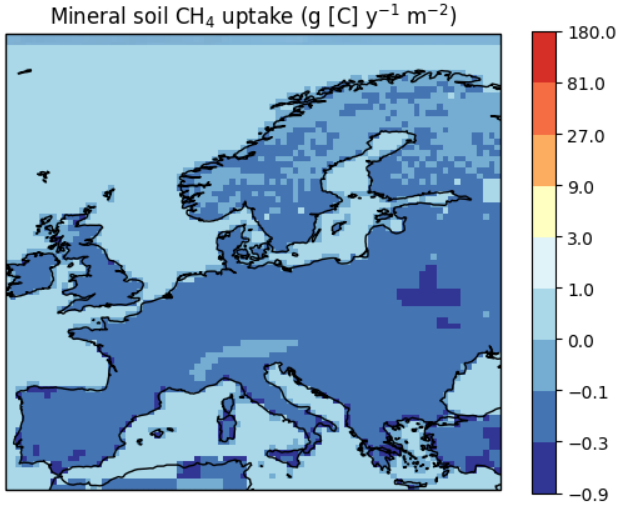
Peat YASSO soil carbon model

WTD, LAI, Resp, Temp

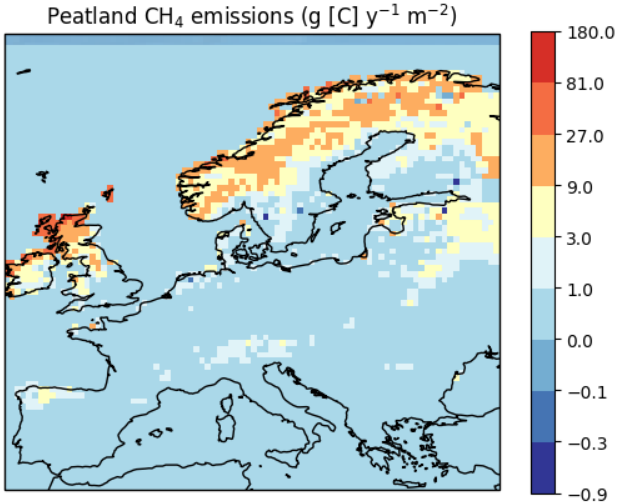


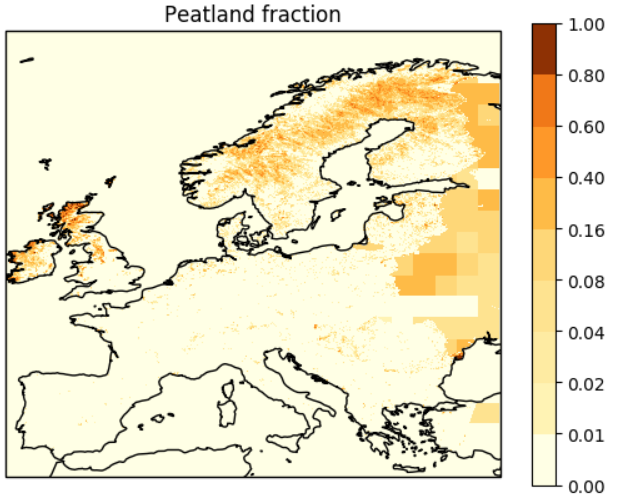
Soil and peatland emissions





Mineral soils both emit and take up methane



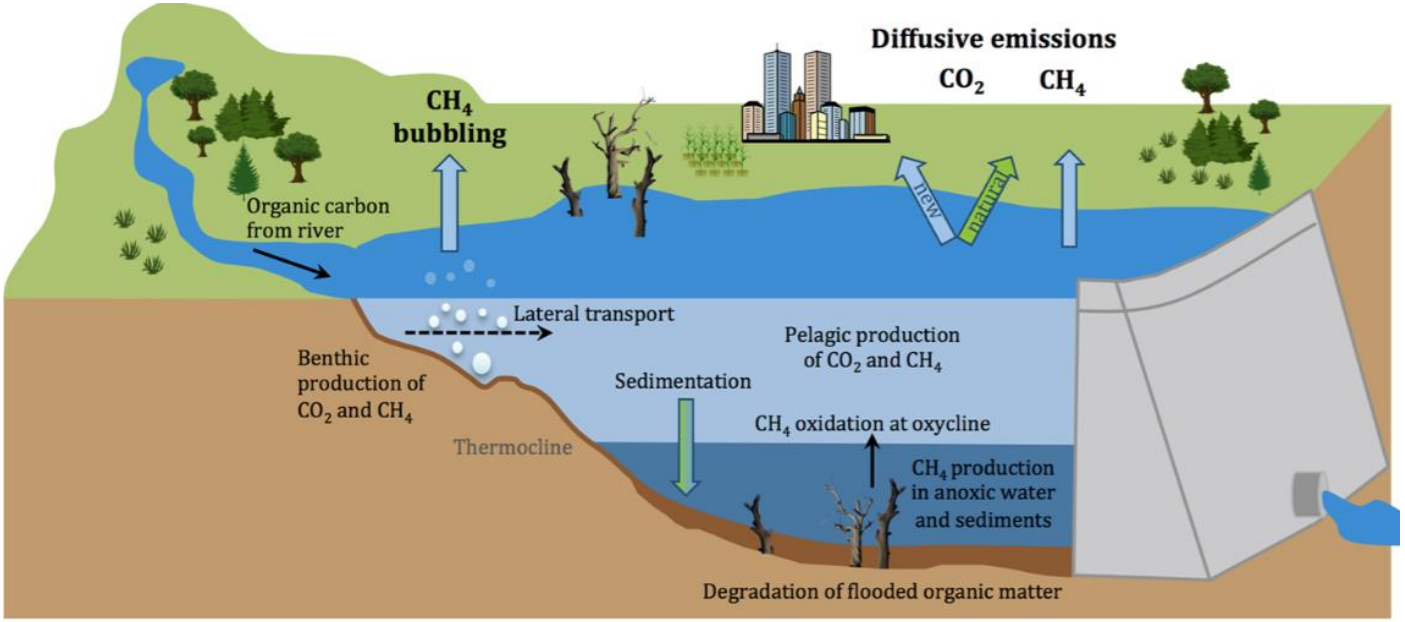


Peatland emissions are predominantly in northern Europe

Inland water body emissions

CH_4 and N_2O fluxes from inland water-systems

- Computes fate of terrestrial-derived & in-situ produced C along the flow path
- Relies on estimates of river (Lauerwald et al., 2015), reservoir (GranD) and lake (HydroLAKES) volumes and surface areas available for gas exchange
- Model inputs: Estimates of terrestrial C and nutrient inputs

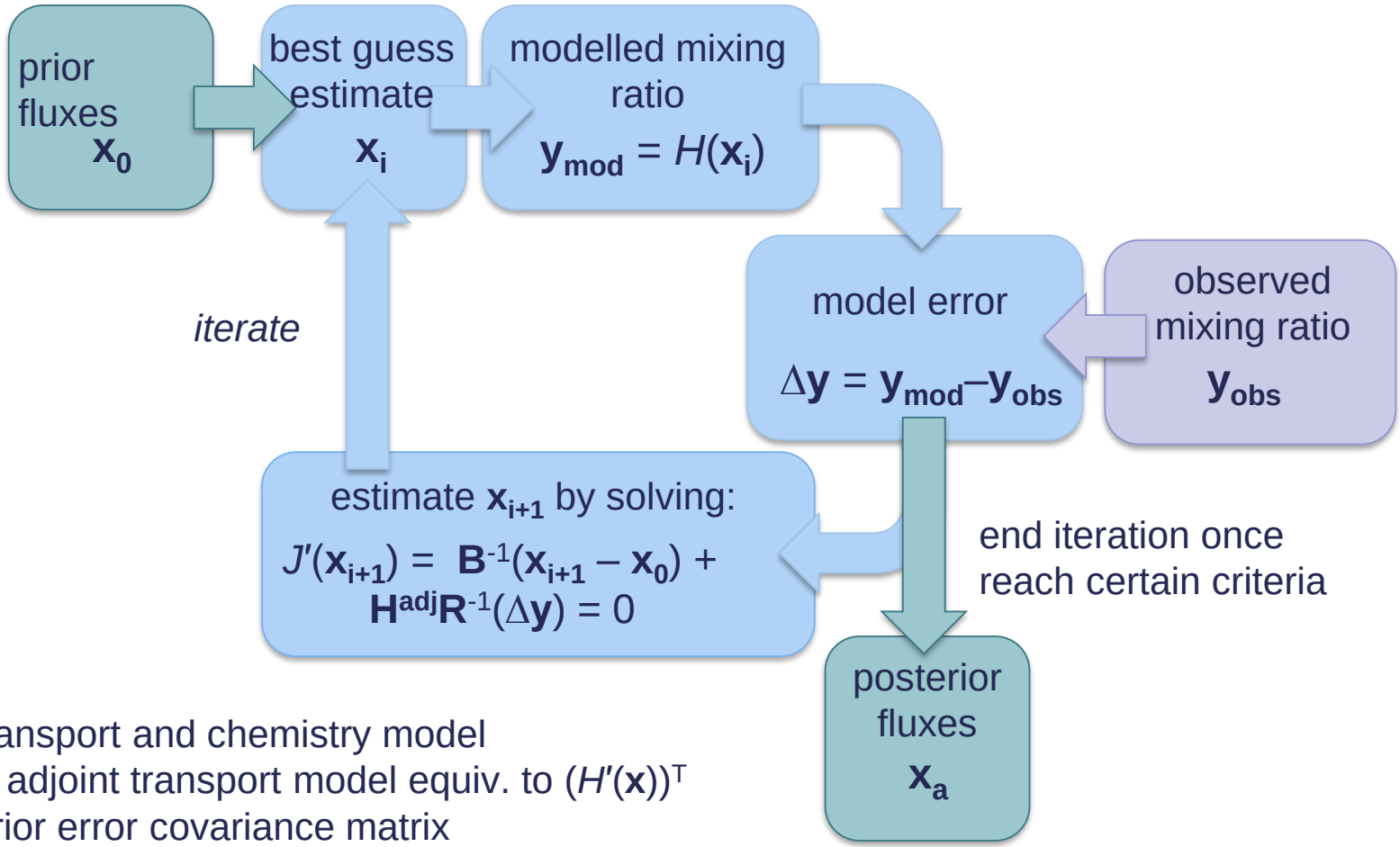


Top-down methods

for estimating CH_4 and N_2O emissions

Inversion method

Based on Bayesian statistics



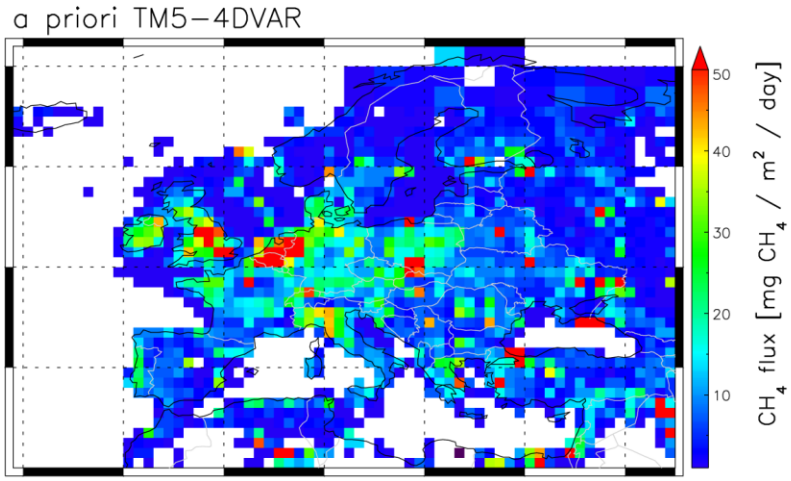
H = transport and chemistry model
$\mathbf{H}^{adj}$ = adjoint transport model equiv. to $(H'(\mathbf{x}))^T$
$\mathbf{B}$ = prior error covariance matrix
$\mathbf{R}$ = obs. error covariance matrix

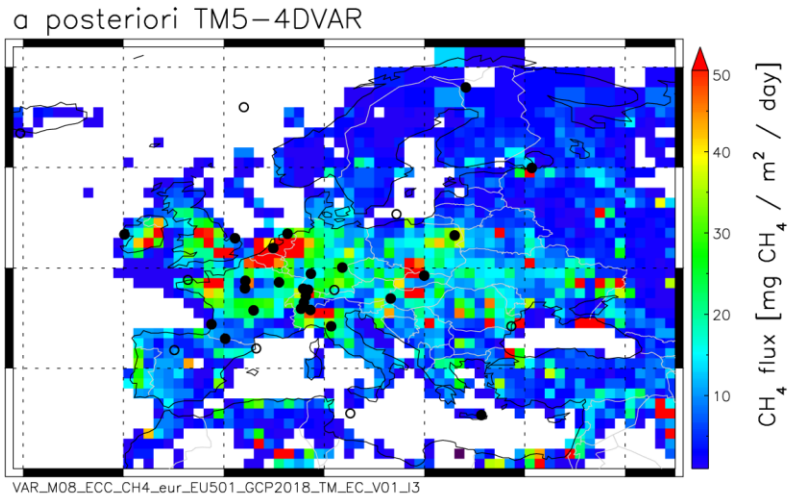
Atmospheric network

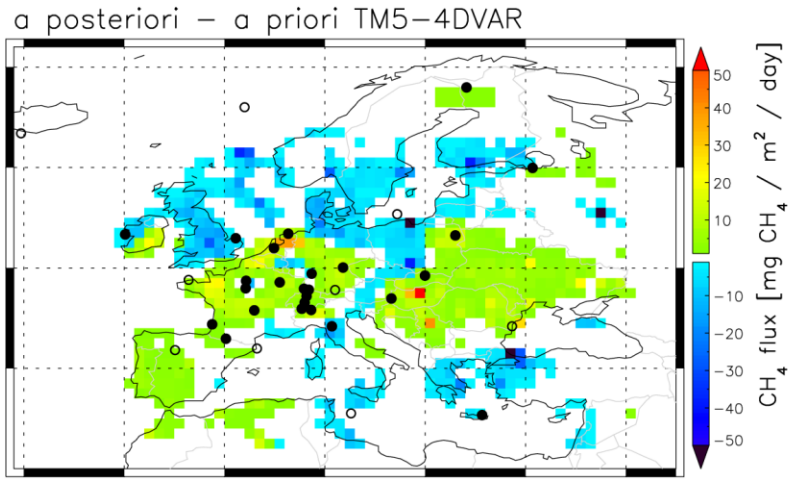
Sites measuring CH_4 and N_2O in Europe

Emission estimates: CH_4

Results 1st year inversions





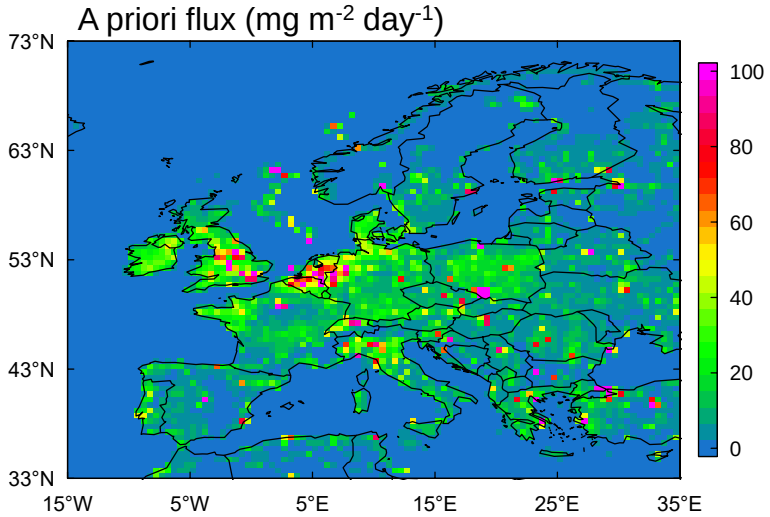


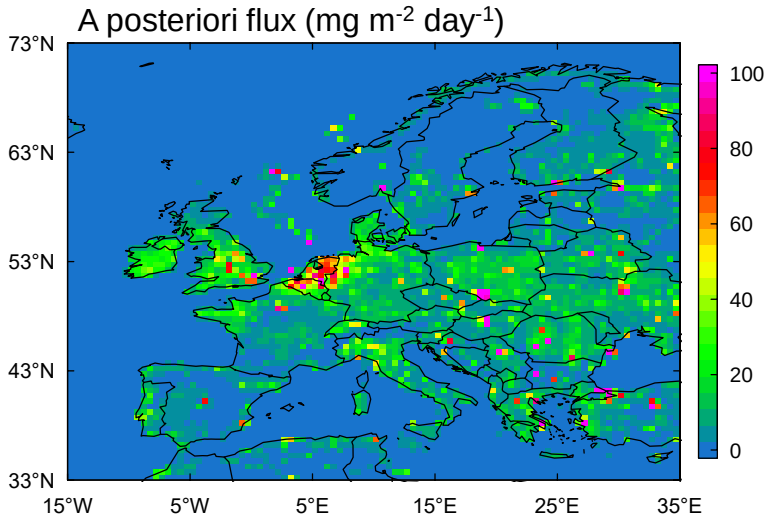
Preliminary results

- Model: TM5-4DVAR
- Global 6°×4°, Europe1°×1°
- Period: 2005-2016
- Priori estimate: GCP-CH_4

Emission estimates: CH_4

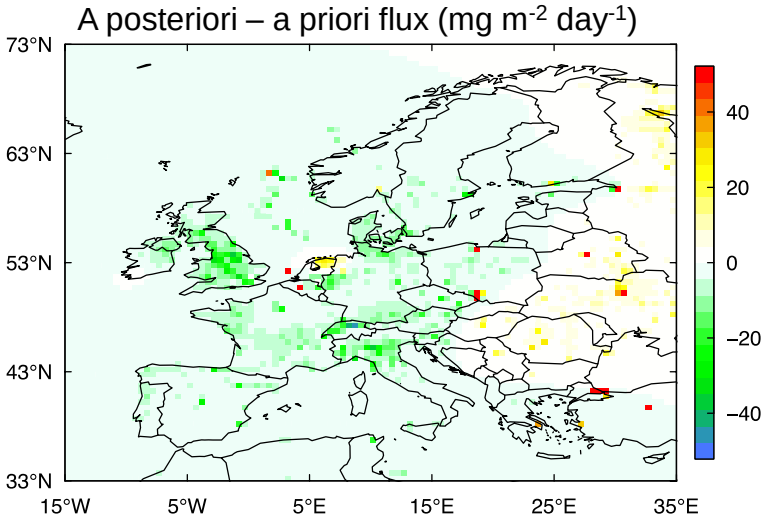
Results 1st year inversions



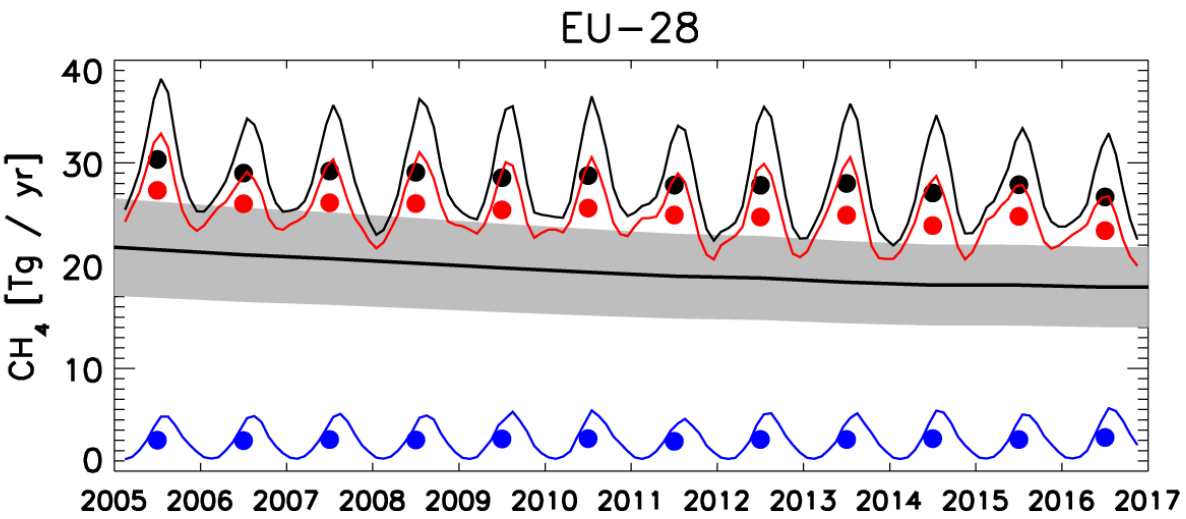


Preliminary results

- Model: FLEXPART-ExtKF
- Resolution: 0.5°×0.5°
- Period: 2005-2016 (shown for 2010)
- Priori estimate: based on EDGAR



Emission trends: CH_4



Preliminary results

- Model: TM5-4DVAR
- Global 6°×4°, Europe1°×1°
- Period: 2005-2016
- Priori estimate: GCP-CH_4

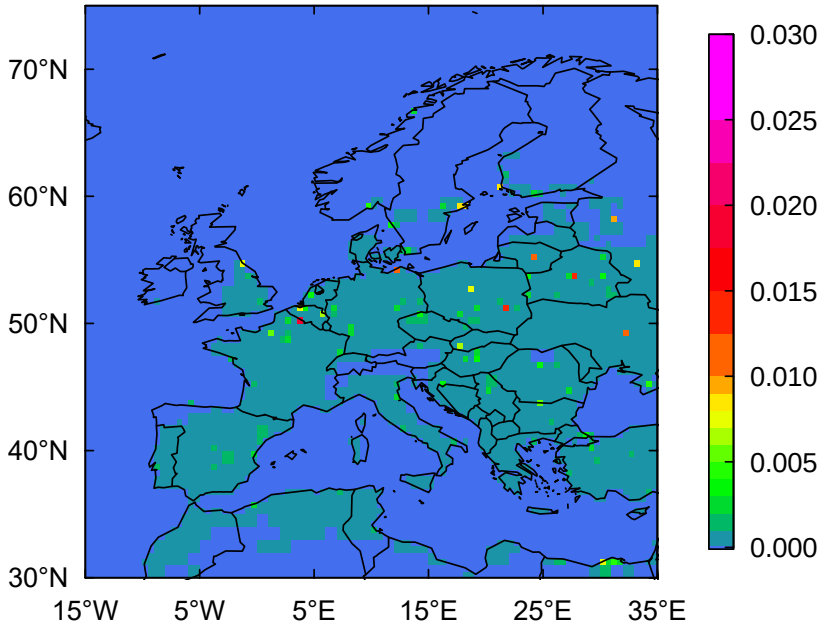
All observations assimilated as available (i.e. not continuous for all stations over 2005-2016 period)

Emission estimates: N_2O

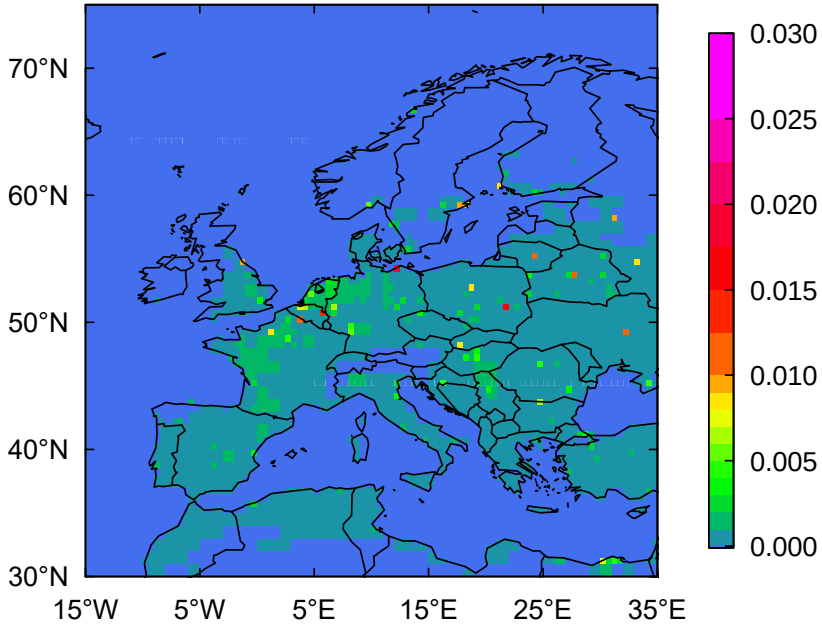
Results 1st year inversions

- Model: FLEXINVERT+
- Resolution: 0.5°×0.5°
- Period: 2005-2015
- Priori estimate: EDGAR-v4.32

Mean prior emissions (gN m^{-2} d^{-1})

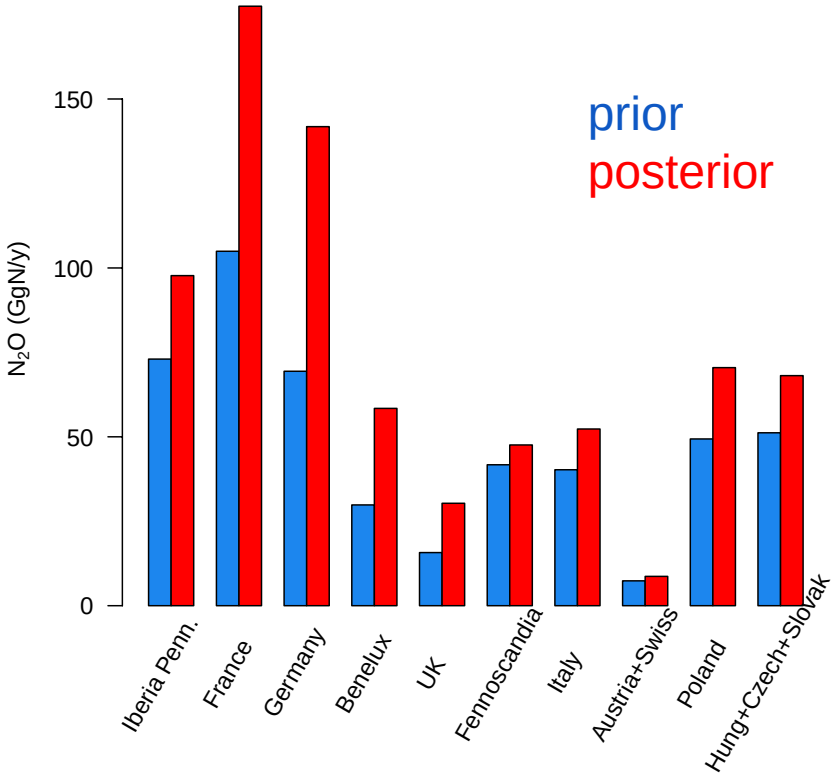


Mean posterior emissions (gN m^{-2} d^{-1})

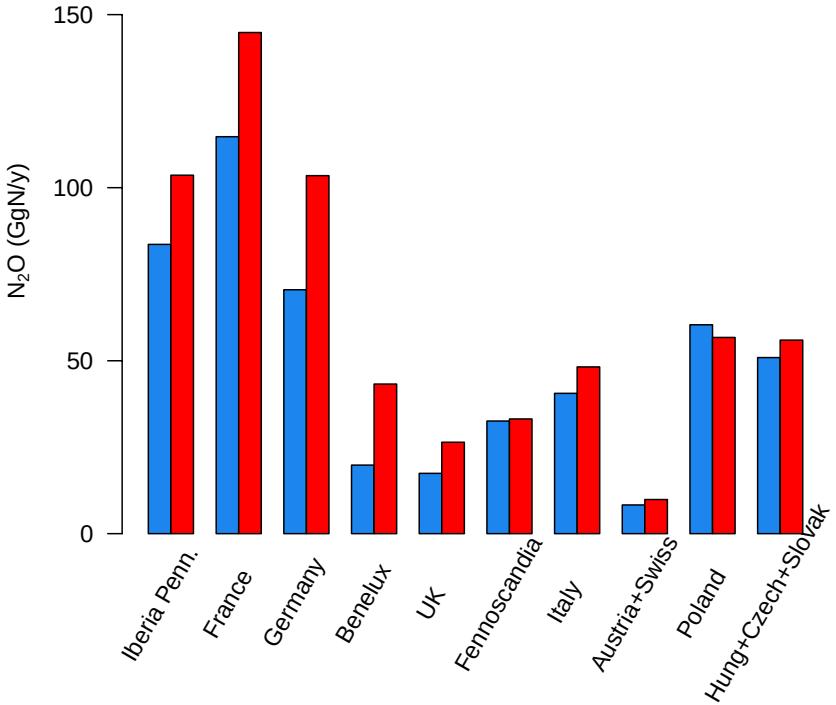


National emissions: N_2O

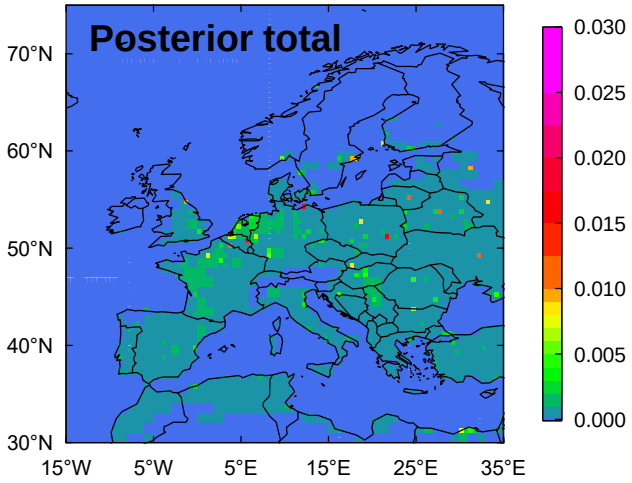
Mean annual emission 2005-2009 (GgN y^{-1})

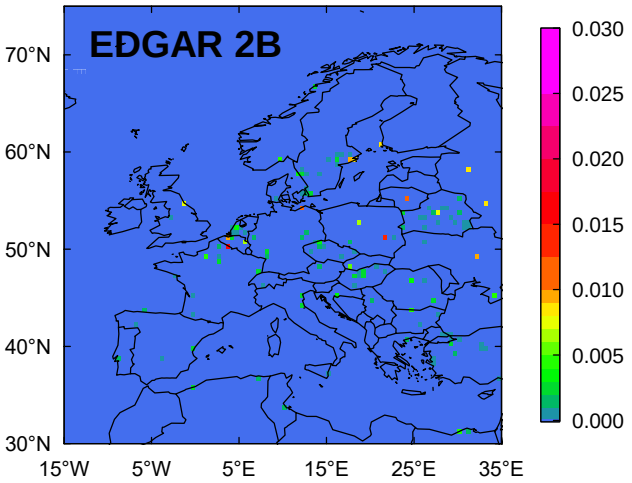


Mean annual emission 2010-2015 (GgN y^{-1})



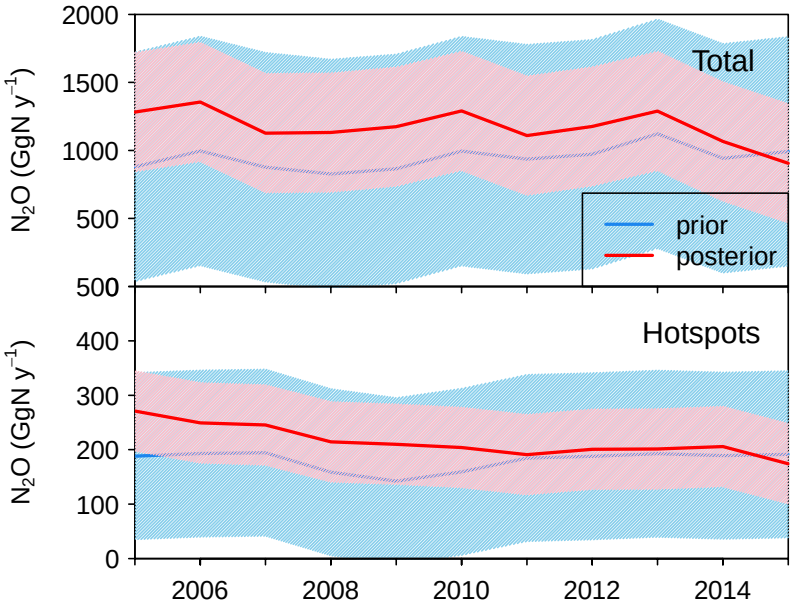
Detection of hotspots: N_2O





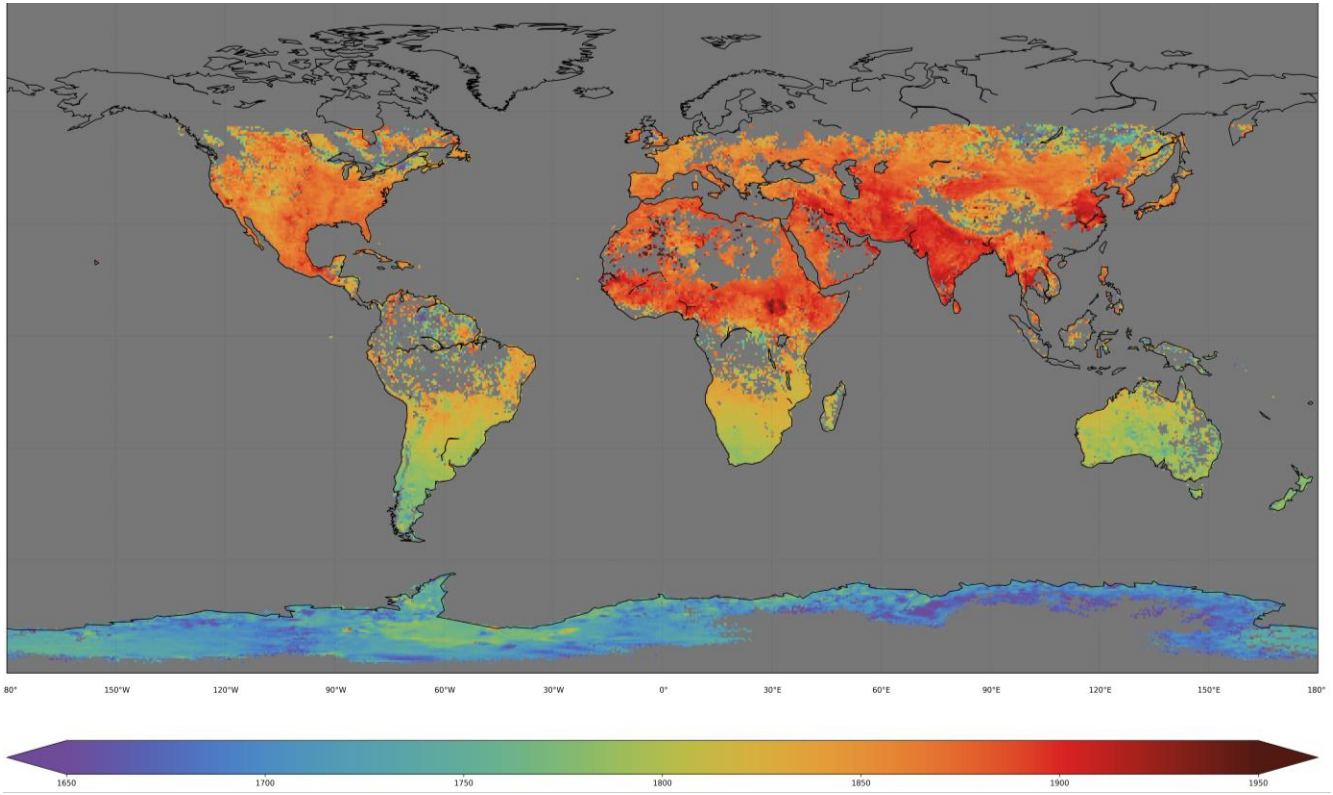
- Only <1% land area responsible for 20% of emissions
- Hotspots defined as >99.5 percentile emissions
- Hotspots largely from nitric and adipic acid production (sector 2B)

Total Land Emissions (GgN y^{-1})



Research & Development

- Using CH_4 retrievals from satellite instrument TROPOMI aboard Sentinel 5P (launched Oct-2017)
- High-resolution 7×7 km



Summary and conclusions

- Bottom-up methods have very large uncertainties on some sources of CH_4 and N_2O leading to very large overall uncertainties
- Potential for top-down methods to contribute to improved emission estimate for these species
- Preliminary inversions show slightly higher CH_4 and N_2O emissions for EU28 compared to UNFCCC reports
- Both CH_4 and N_2O show a small decreasing trend over 2005-2016