Co-authored by the TNO emissions team:

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OUTLINE

- Using emission inventories in modelling
  - What do inventories offer, and what do modellers need?
  - Work done in Copernicus Atmospheric Monitoring Service (CAMS) and how that compares to the national inventories

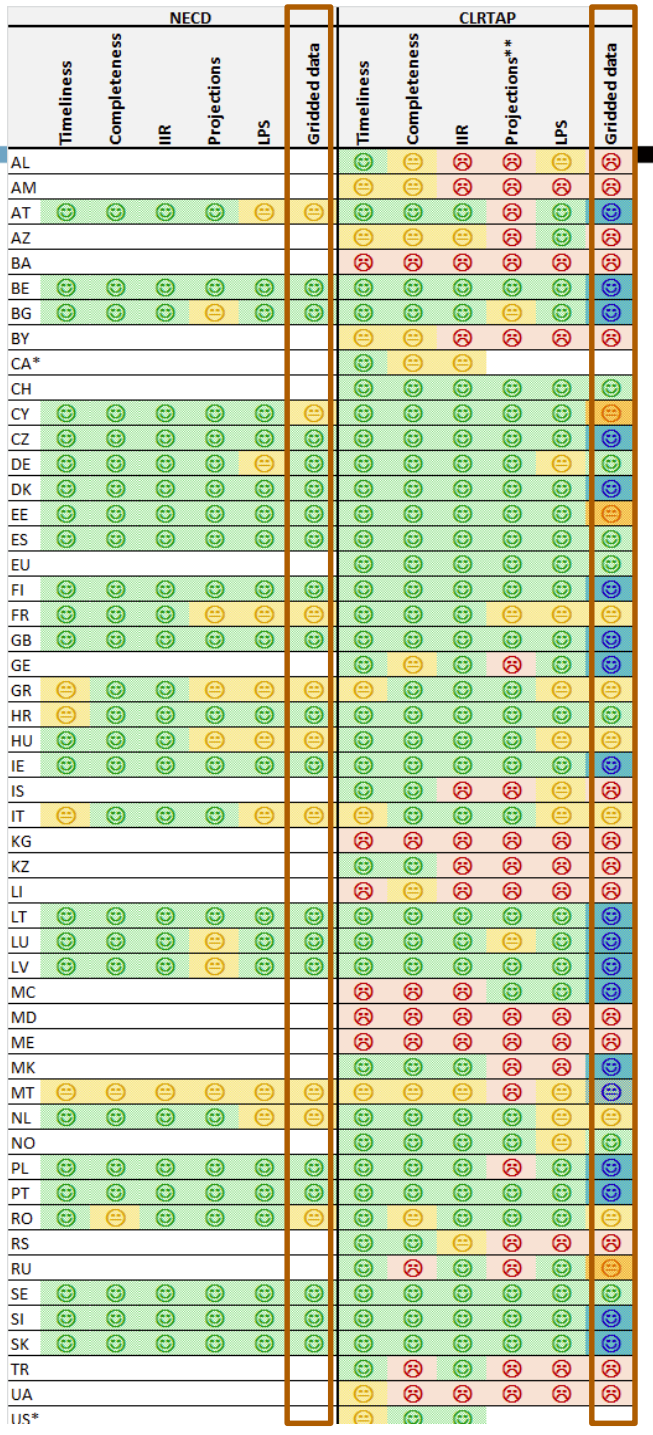
- Important aspects for modellers
  - Consistency in emissions (in various aspects)
  - Fine time scale emissions (from annually to hourly)

WHAT DO USERS REQUEST?

	Country Inventories	Model user needs & wishes
What?	• Releases of pre-defined list of pollutants from pre-defined list of sources (NFR)	• All sources, also int'l • Some sources more detail (fuels) • Split of some of the reported pollutants (NOx, PM, NMVOC) in actual components
Where?	• Country level data • Grid level data 0.1°x0.1°	• Increasing demand for higher resolution (1-3km)
When?	• Annual time scale • Reporting in year t-2	• Hourly time scale is requested for modelling activities • No delay (from t-2 to NRT?)
How?	• Following the Guidelines & Guidebook	• More consistency in emissions necessary in specific cases

GRIDDED DATA REPORTING

- Reporting provides gridded data at 0.1°x0.1° resolution, but…
  - Gridded data & LPS reporting only every 4 years (2017, 2021, …)
  - Many countries missing, especially outside EU
  - Data holds has errors (e.g. lat/lon coordinates)
  - Consistency at borders?
- Work ongoing to improve (e.g. ongoing NECD review), but for the time being an alternative is needed for modellers

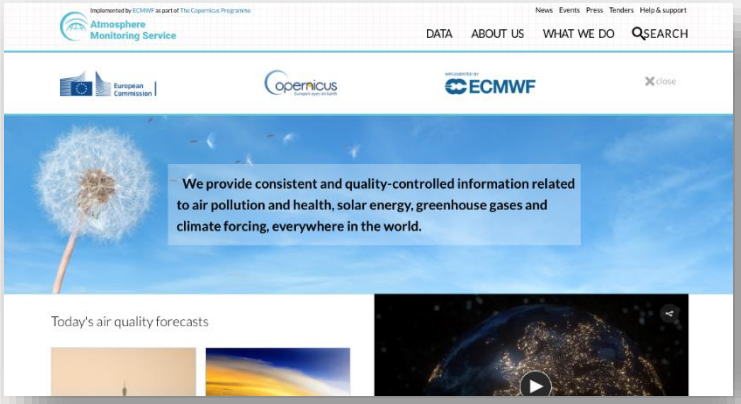


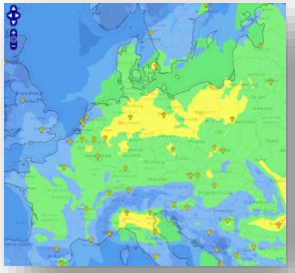

opernicus
CLIMATE CHANGE
MARINE MONITORING
ATMOSPHERE MONITORING
LAND MONITORING
SECURITY
EMERGENCY MANAGEMENT

THE CAMS PORTFOLIO

Atmosphere Monitoring

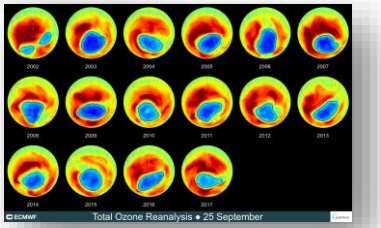
atmosphere.copernicus.eu



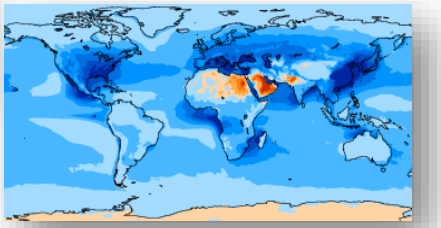


European Air Quality and products in support of policy users

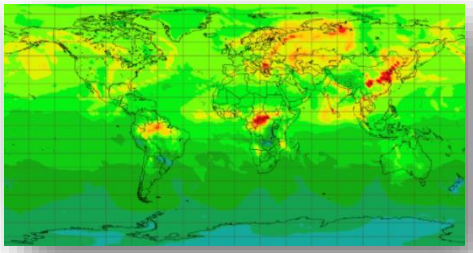
Ozone layer



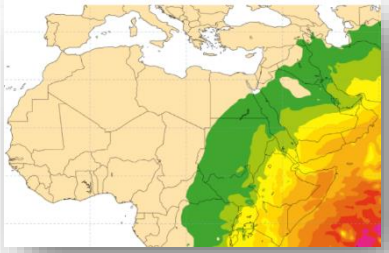
Climate forcings



Bottom-up emissions and surface fluxes of greenhouse gases



Global analyses, forecasts and reanalyses (2003-...)



Solar radiation and UV index

TNO

From V-H Peuch, ECMWF

CAMS EMISSION INVENTORY

- Pan-European scale, i.e. not bound to specific countries but defined along coordinates covering the entire continent
- Not only emissions for regulated pollutants, but also includes a split of PM10, PM2.5 and NMVOC in different components
- Covering also major greenhouse gases (CO_2, CH_4) (N_2O to be added later)
- Longer time series (2000-2015 annually, 2000-2017 currently under evaluation)
- Input format directly usable for modellers (CSV and NetCDF formats)

CAMS-REG METHODOLOGY

Official reported emissions (CEIP/UNFCCC)

GAINS emission dataset

Modifications & other estimates

- Inland waterways
- Agricultural waste burning
- NOx/NMVOCs from agriculture

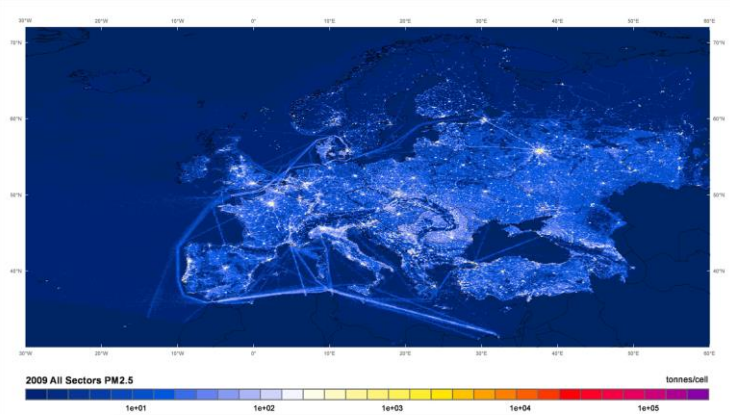
~ 250 subsectors, based on NFR with main fuel splits

CAMS 81 emissions by subsector

Int. shipping *(AIS based, FMI)*

Spatial proxies

- Population
- Road transport
- Animal densities
- E-PRTR, etc. etc.



CAMS regional emission product

Copernicus
Europe's eyes on Earth

Atmosphere Monitoring Service

DATA USED FOR PUBLIC POWER AND HEAT SECTOR, EU

LCP
Plant name
Location
Plant type
Emission of NOx, SOx and dust
Fuel use by fuel type
→Estimated CO2 emissions
Years: 2004 – 2015

Gapfilling from LCP dataset:
- Fuel type
- Emissions of NOx, SOx, dust and CO2 when missing in EPRTR dataset
- Plants when missing in EPRTR dataset

E-PRTR
Facility name
Location
Sector
Emissions of CO2, NOx, SO2 and PM10
Years: 2001, 2004, 2007–2015

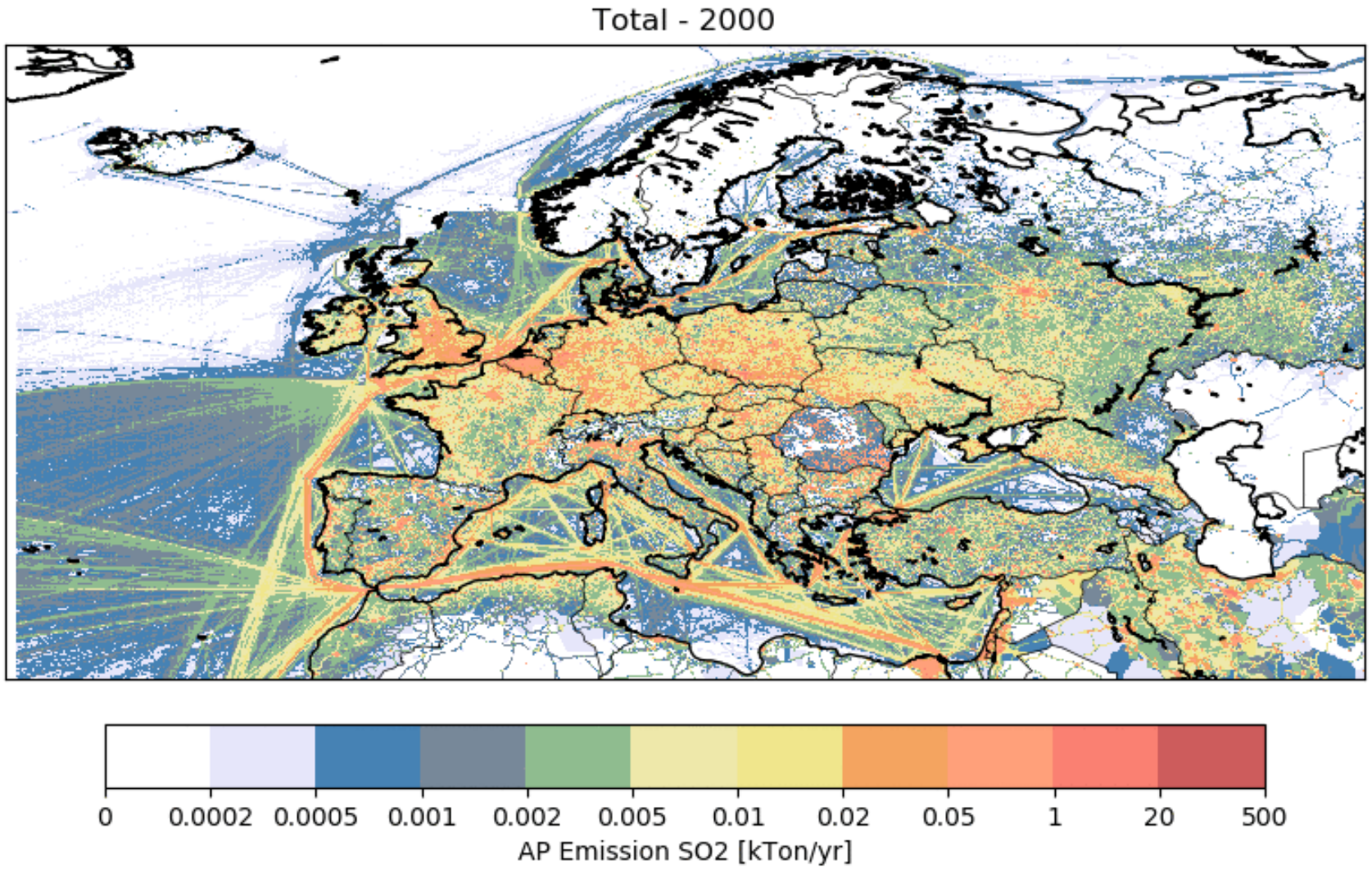
Creating final product

Platts WEPP
Plant name
Location
Unit type
Fuel type
Electric capacity
Sector (e.g. utility, autoproducer in paper prod.)
Year start of operation
Year retired (if applicable)

Gapfilling from Platts WEPP dataset:
- Fuel type when missing in LCP dataset (e.g. waste plants)
- Crosscheck to see if all large electricity plants have been included
- Crosscheck with sector to see if facility is part of Public power and heat sector

Combined TNO dataset
Facility name
Location (coordinate + country)
Fuel type
Pollutant
Emission
Share of plant in country emissions by fuel type

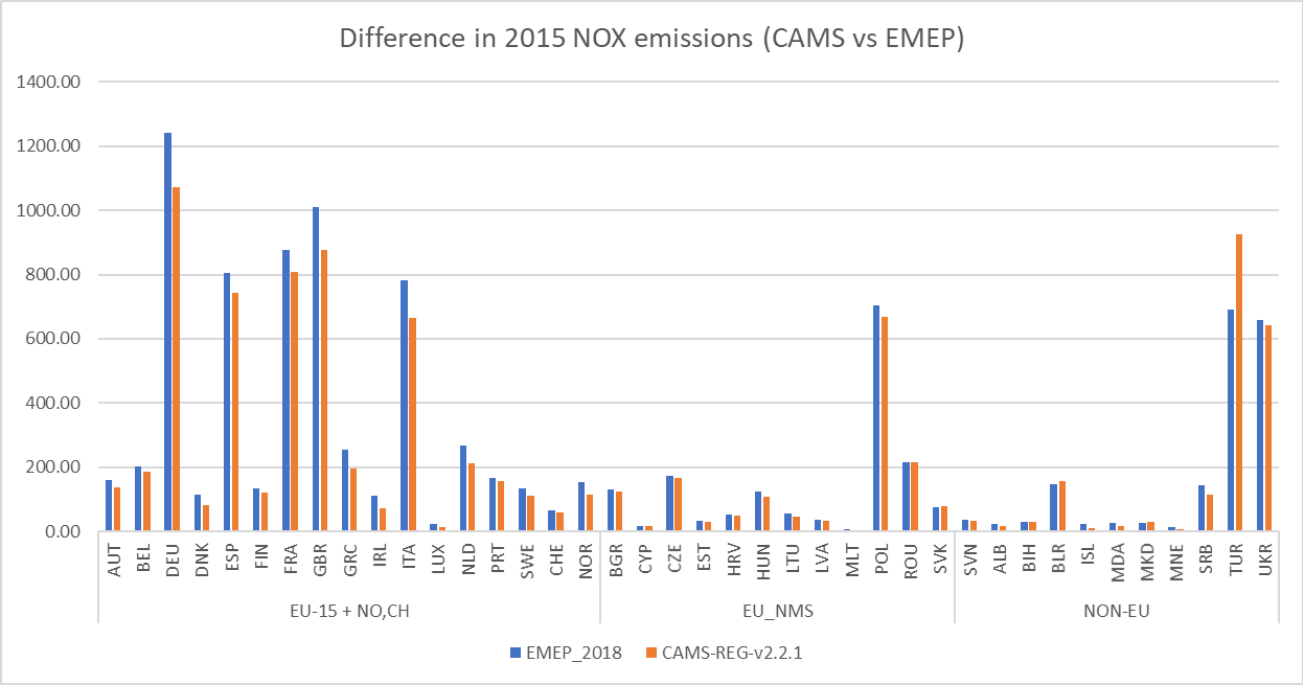
EXAMPLE: SO2 TIME SERIES



COMPARING CAMS AND EMEP

- Different issues play a role, also coverage of sources
- Example: some countries report significant NOx emissions from agricultural soils
  - Currently these are excluded from CAMS-REG as some models calculate these separately

Country	NOX in L_AgriOther	
DE	129	32%
ES	58	15%
IT	47	12%
IE	30	7%
NL	30	7%
GR	19	5%
DK	17	4%
SE	13	3%
BE	12	3%
AT	11	3%
FI	9	2%
NO	7	2%
GB	6	1%
PT	5	1%
FR	4	1%
CH	3	1%
LU	1	0%

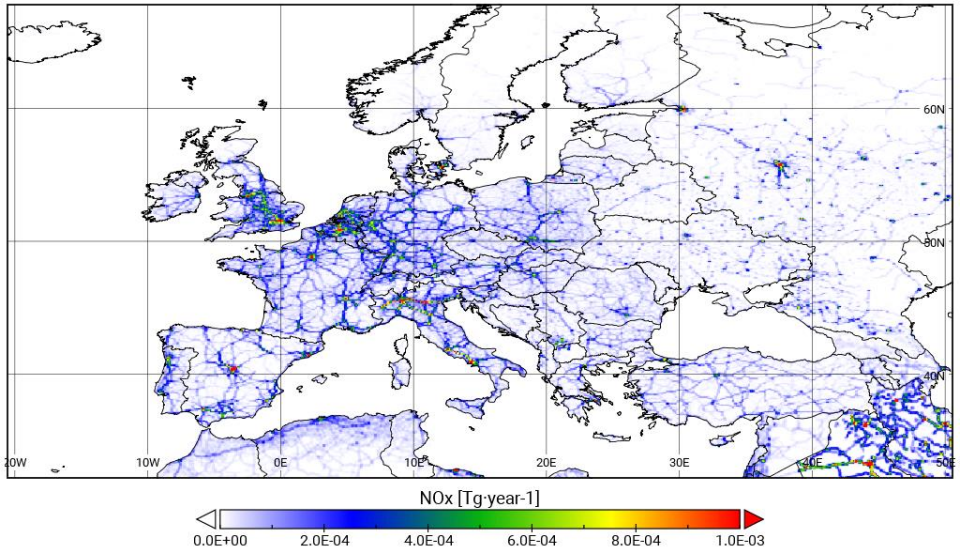


Poll	CAMS	EMEP	Diff
NOX	9611	9975	-4%
SOX	6821	6504	5%
NMVOC	7868	9303	-15%
NH3	5127	5239	-2%
PM2.5	2442	2082	17%

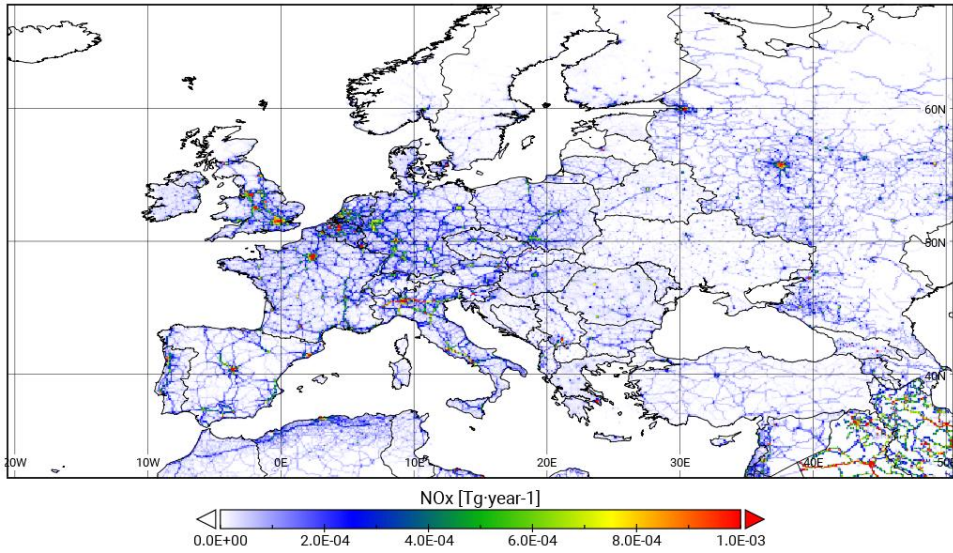
COMPARISON OF GRIDDED DATA

- Comparing EMEP gridded data (2019) to CAMS-REG-v2.2.1
- Example 1: NOx from Road transport

CAMS-REGv221 (NOx GNFR14 sector F RoadTransport - 2015



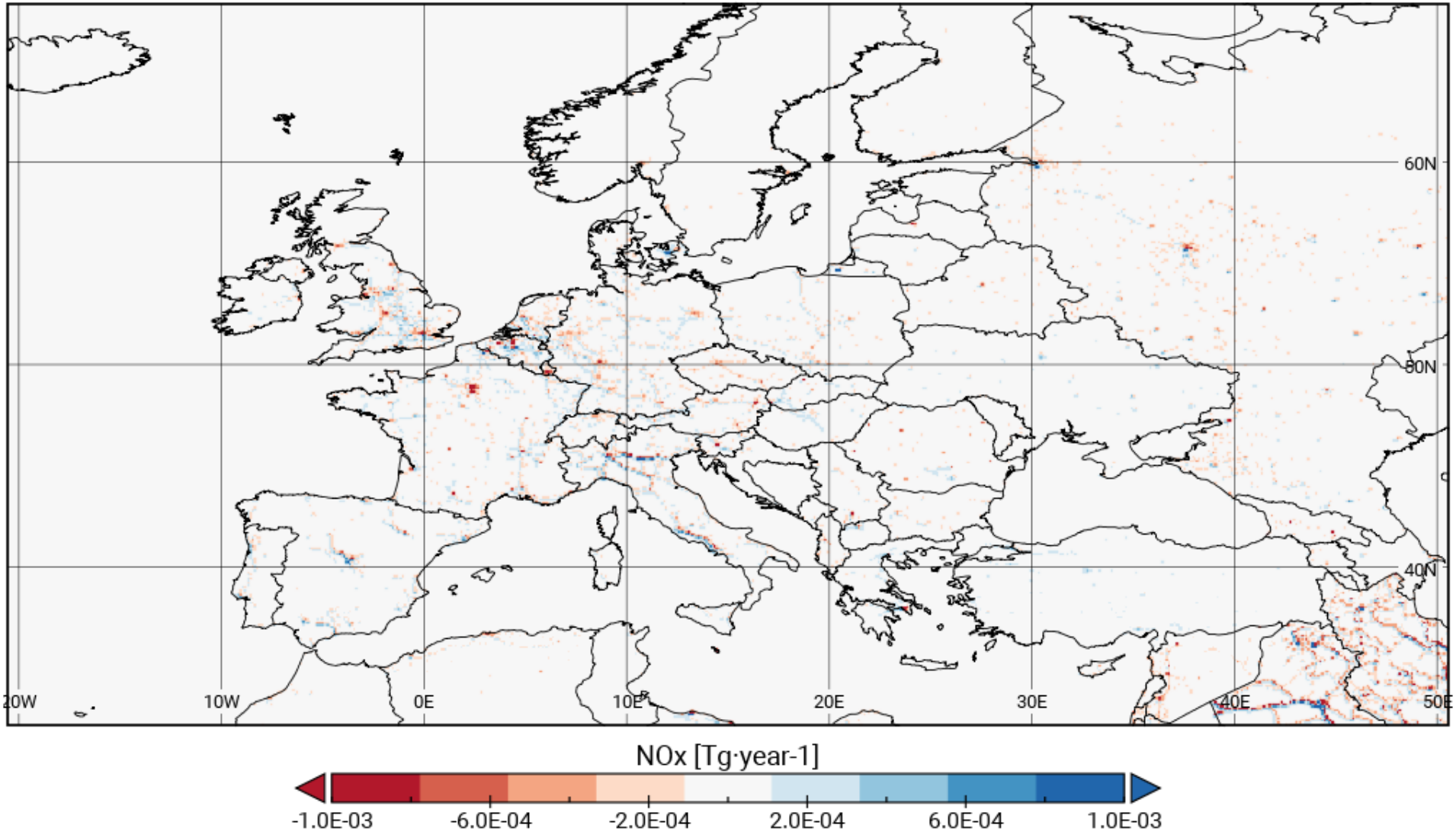
EMEPv2019 (NOx GNFR14 sector F RoadTransport - 2015)



FAIRMODE
Forum for air quality modelling in Europe

Comparison: Marc Guevara (BSC)

CAMS-REGv221 - EMEPv2019 (NOx GNFR14 sector F RoadTransport - 2015)



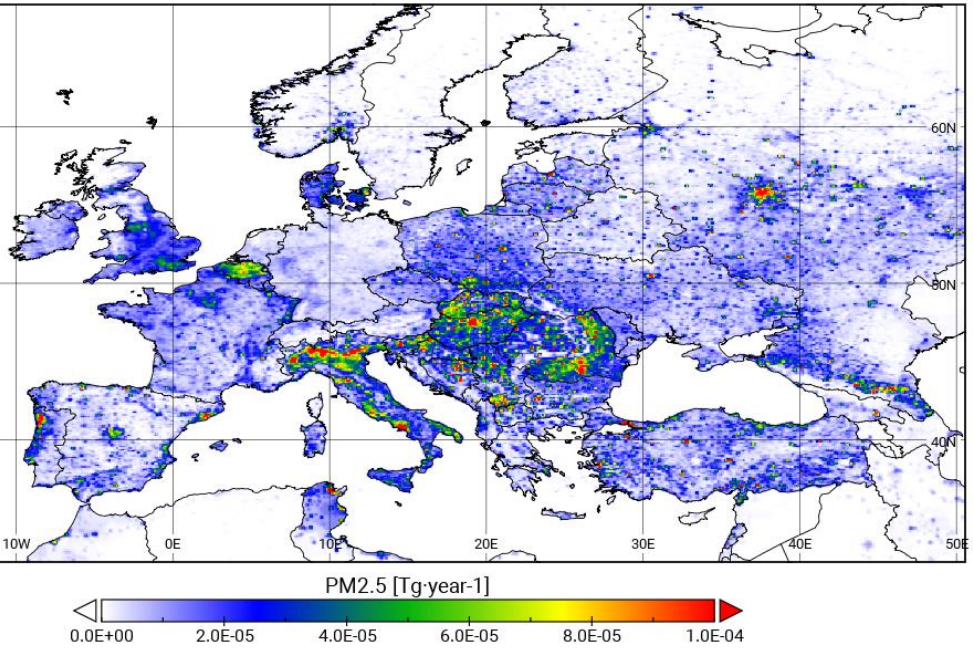
FAIRMODE
Forum for air quality modelling in Europe

Comparison: Marc Guevara (BSC)

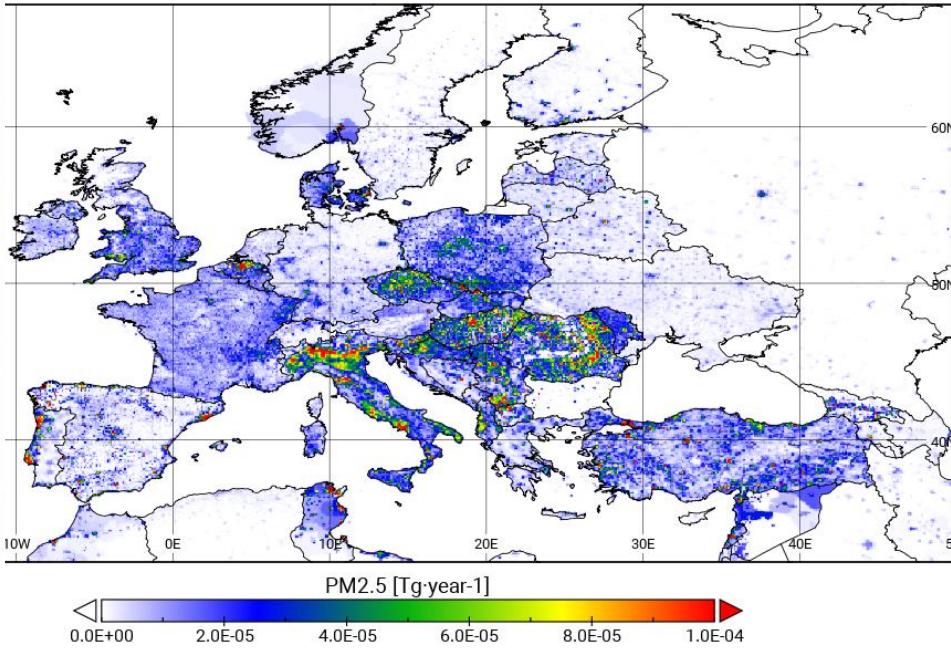
COMPARISON OF GRIDDED DATA

- Example 2: PM2.5 from small combustion

CAMS-REGv221 (PM2.5 GNFR14 sector C OtherStationaryComb - 2015)



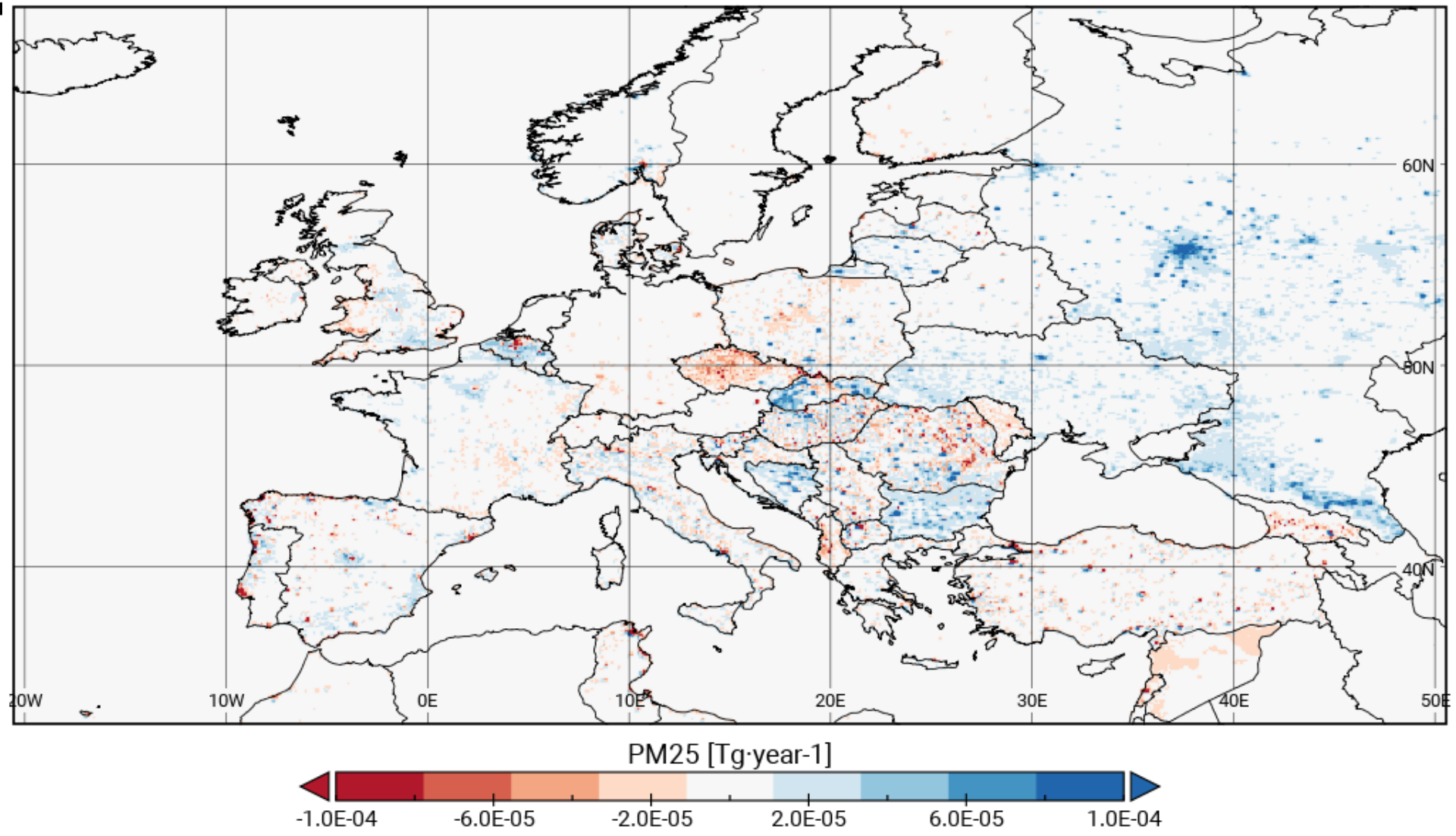
EMEPv2019 (PM2.5 GNFR14 sector C OtherStationaryComb - 2015)



FAIRMODE
Forum for air quality modelling in Europe

Comparison: Marc Guevara (BSC)

CAMS-REGv221 - EMEPv2019 (PM25 GNFR14 sector C Otherstationarycomb - 2015)



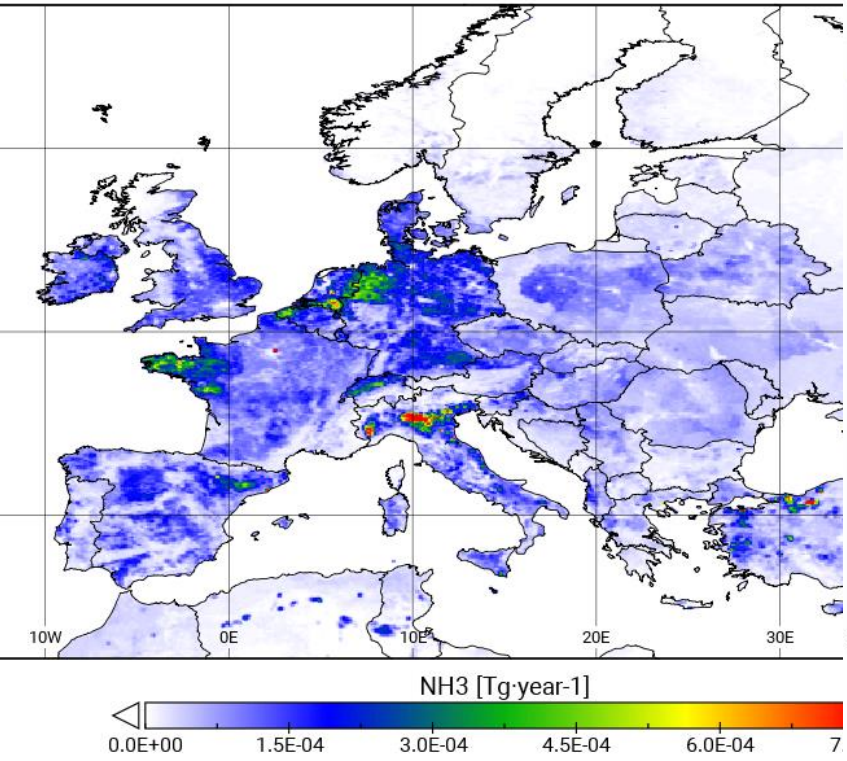
FAIRMODE
Forum for air quality modelling in Europe

Comparison: Marc Guevara (BSC)

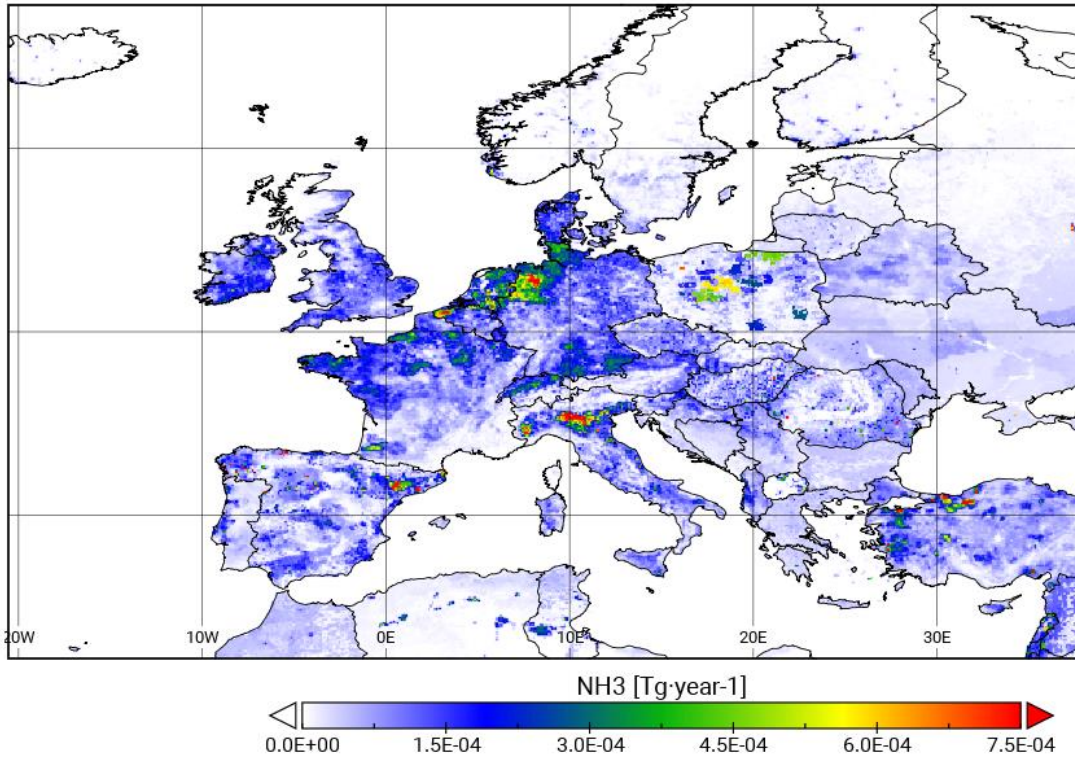
COMPARISON OF GRIDDED DATA

- Example 3: NH3 from agriculture

CAMS-REGv221 (NH3 GNFR14 sector K + L Agriculture)



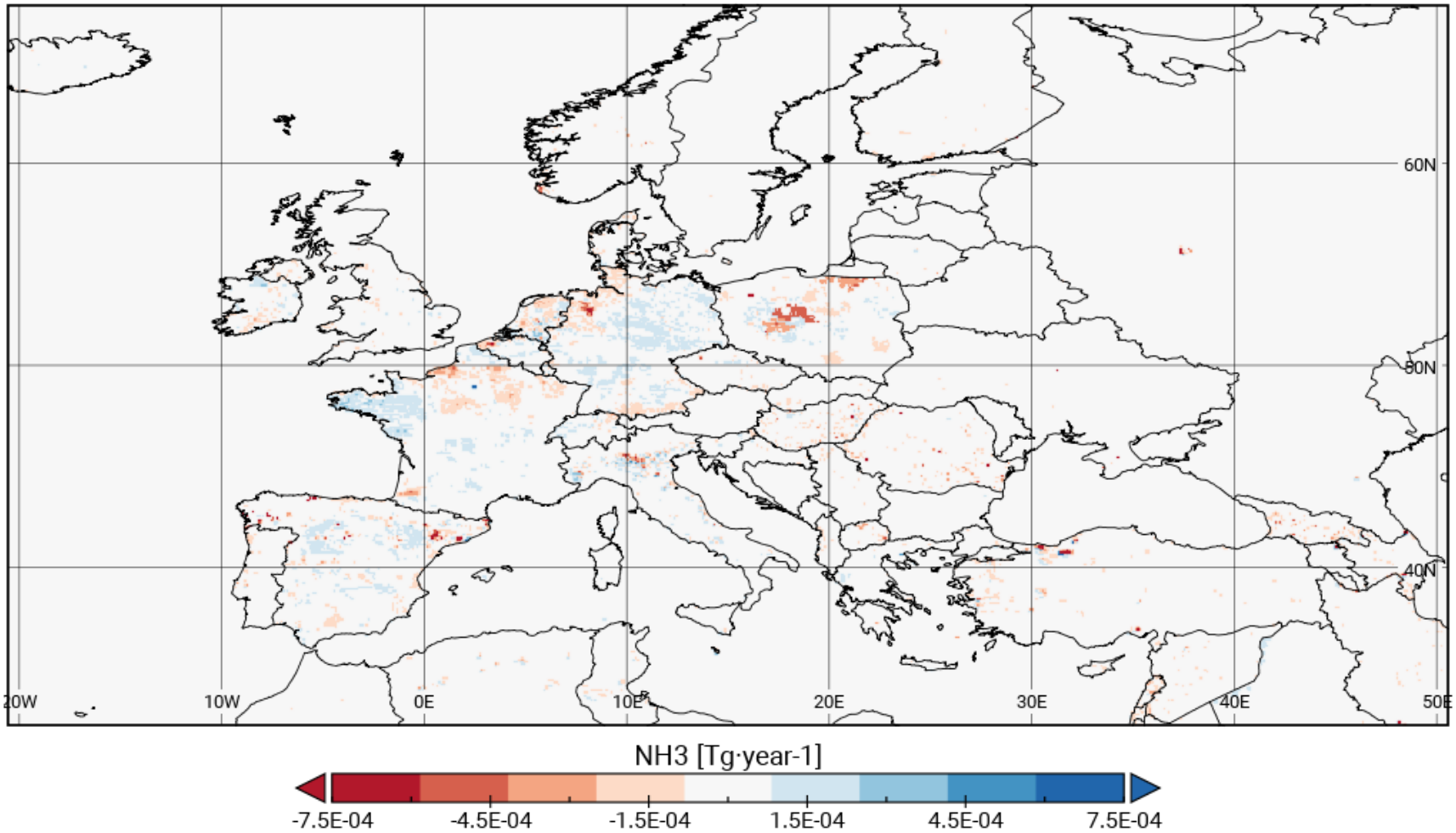
EMEPv2019 (NH3 GNFR14 sector K + L Agriculture)



FAIRMODE
Forum for air quality modelling in Europe

Comparison: Marc Guevara (BSC)

CAMS-REGv221 - EMEPv2019 (NH3 GNFR14 sector K + L Agriculture)



FAIRMODE
Forum for air quality modelling in Europe

Comparison: Marc Guevara (BSC)

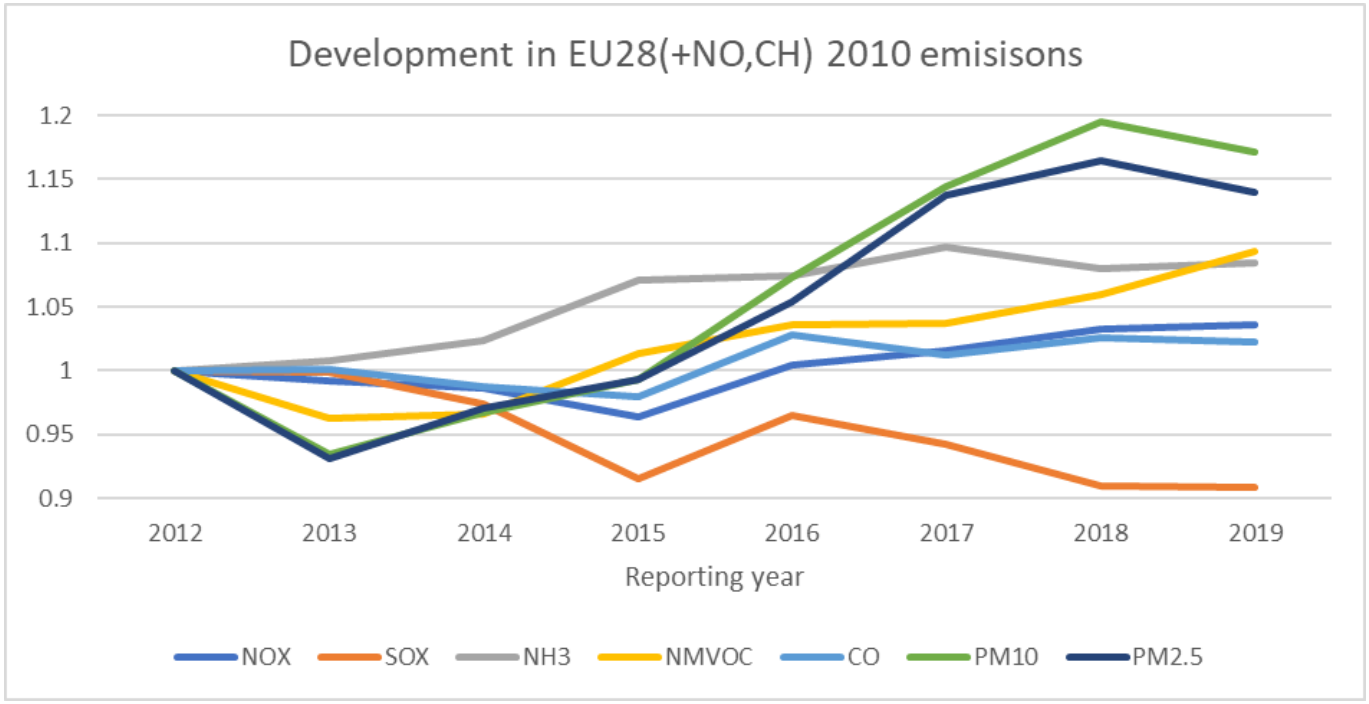
CONSISTENCY IN EMISSION REPORTING

- CAMS inventory based on official reported data (from NFR tables)
  - Data are taken up from a certain reporting cycle

- However, modellers are often not aware that these data are resubmitted annually => yet these recalculations can be very significant!
- In addition, inventories are not always fully consistent between countries

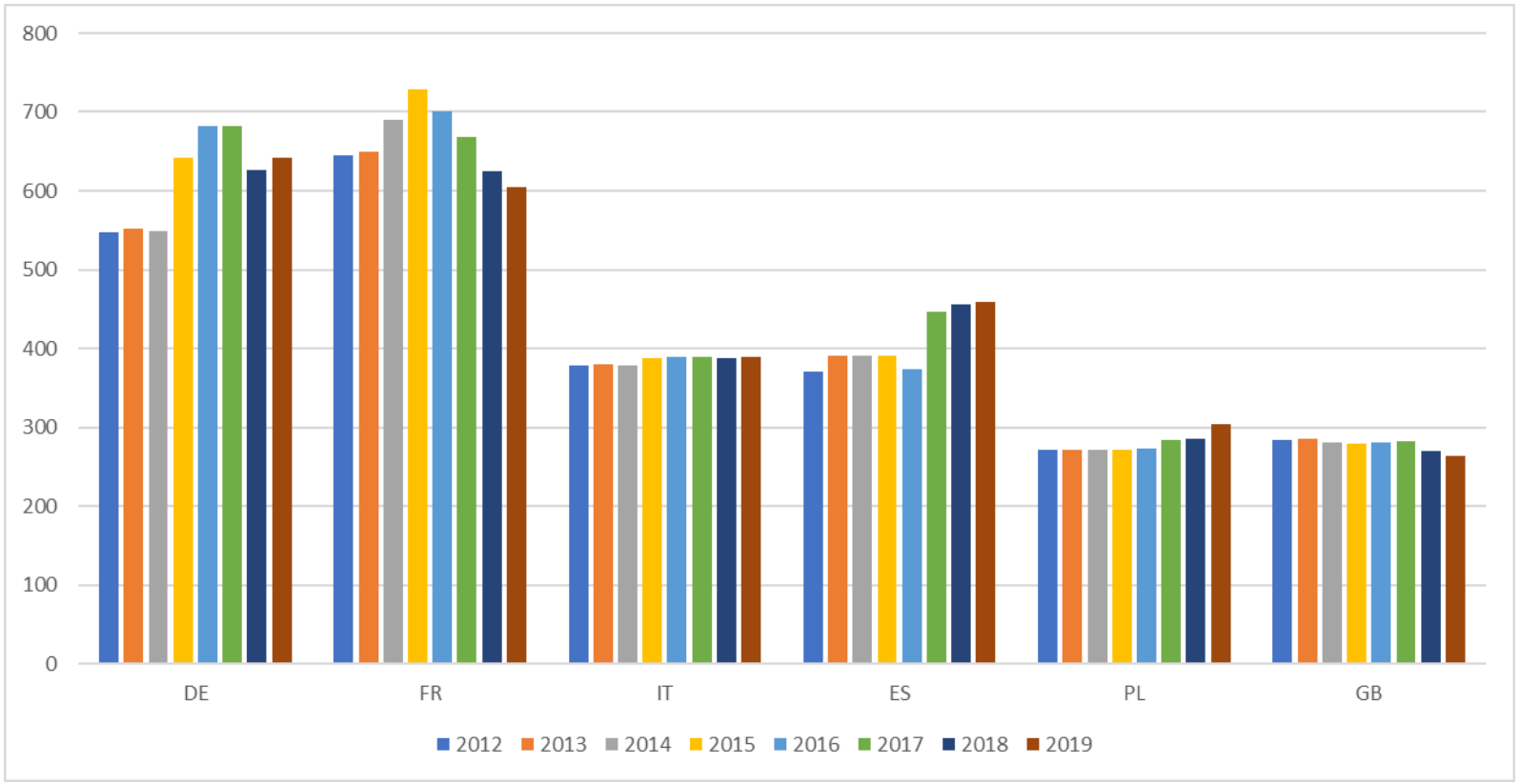
RECALCULATIONS

- Emissions are recalculated annually for the full time series
- In some cases, strong interannual variations are observed for historical emissions



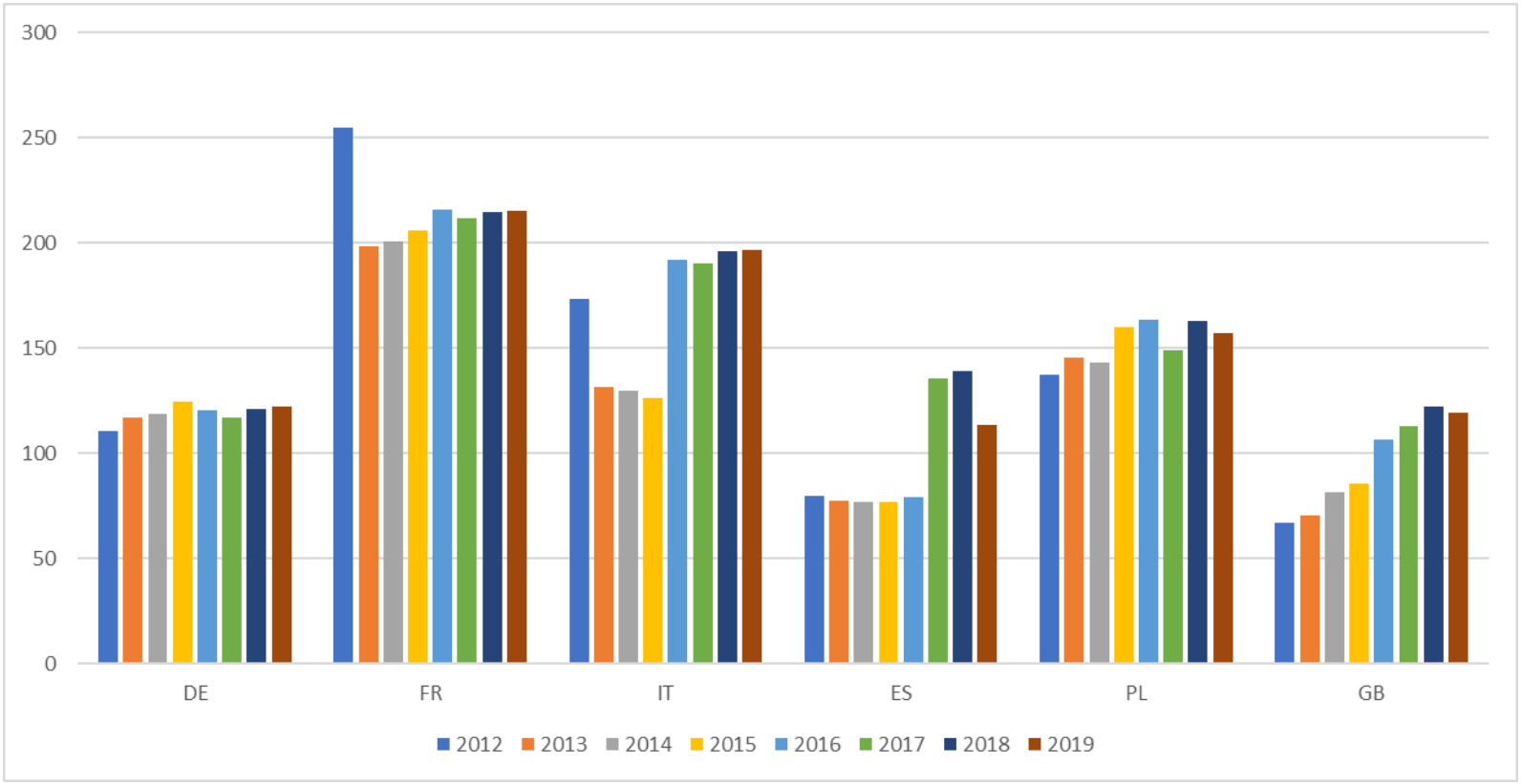
SOME EXAMPLES

NH3 emissions in year 2010 (selected countries) reported in different years

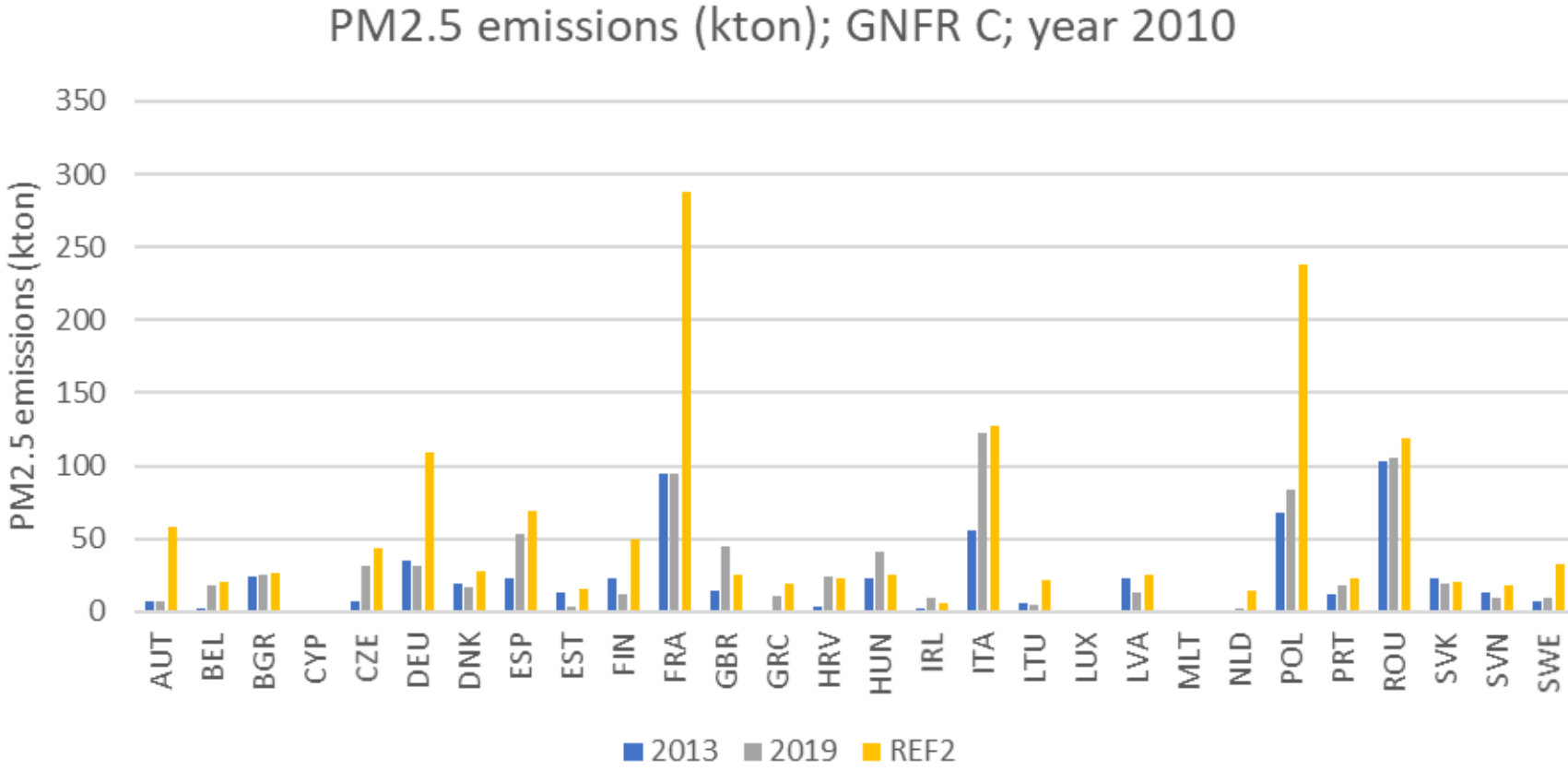


SOME EXAMPLES

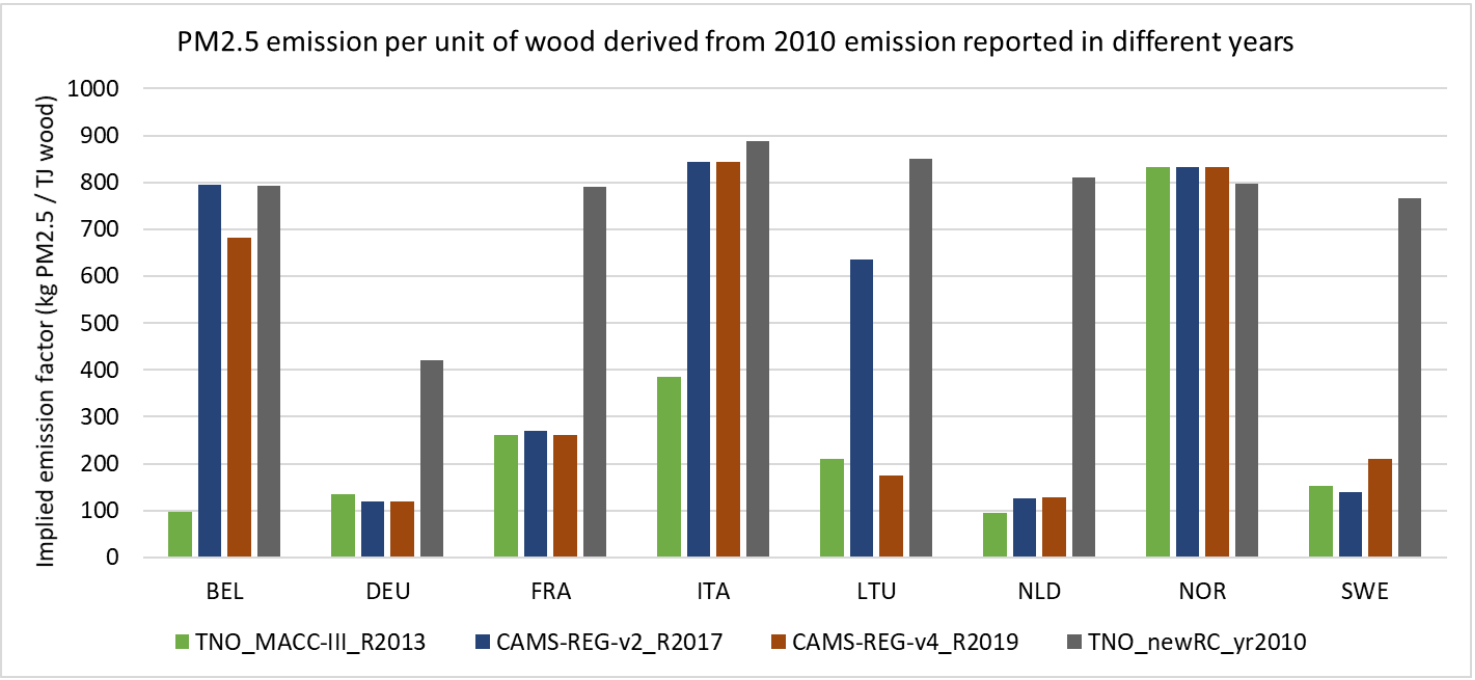
PM2.5 emissions in year 2010 (selected countries) reported in different years



BUILDING CONSISTENCY

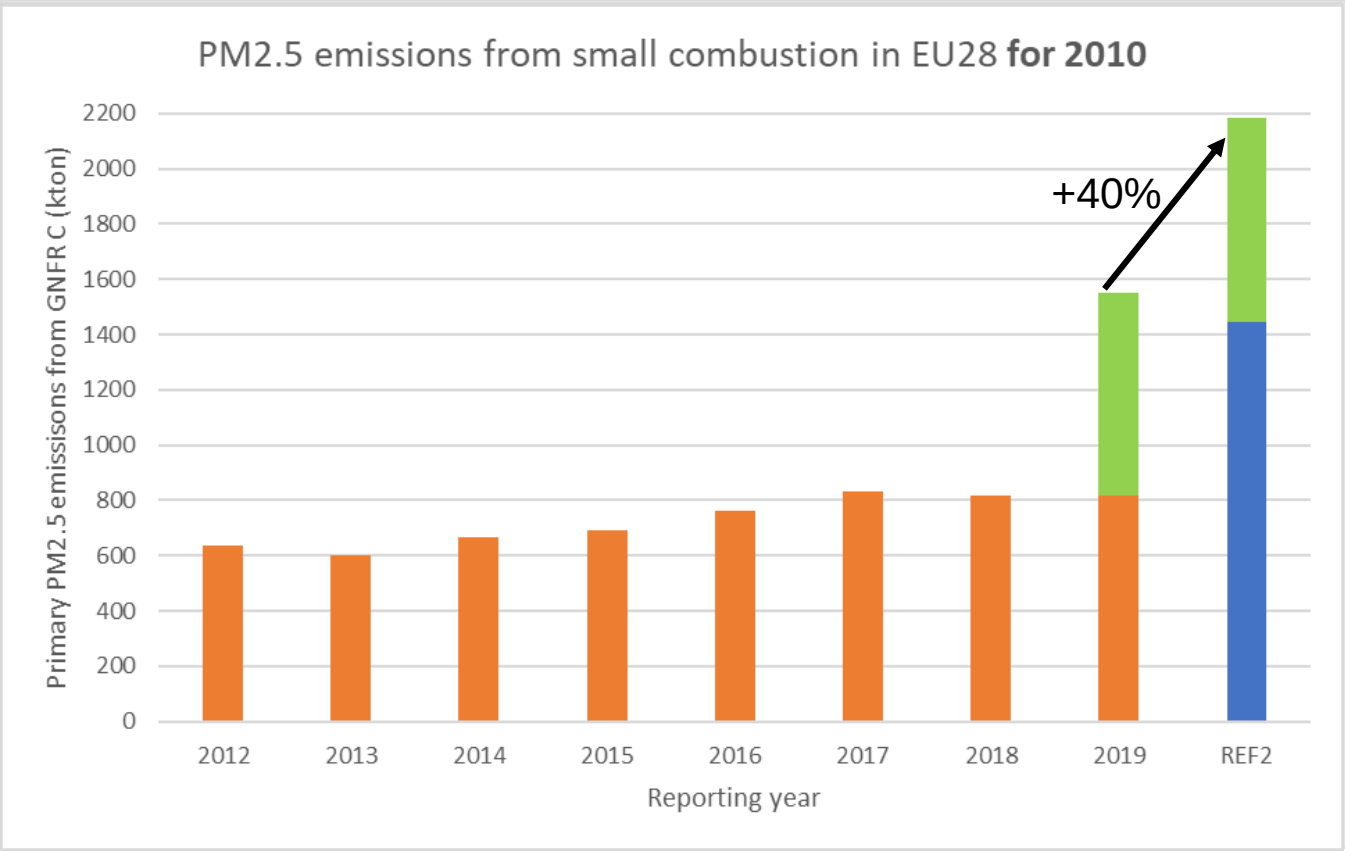


EMISSION PER UNIT OF WOOD



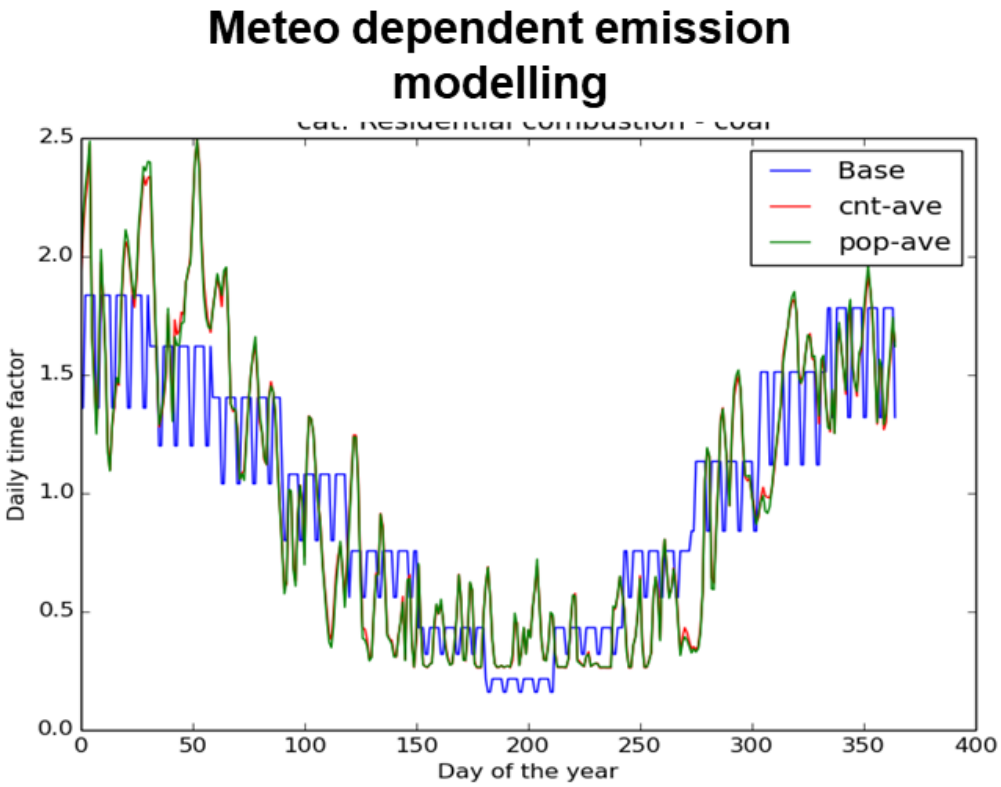
- Implied emission factors show range of factor 8 difference (“crude” analyis)
- Bottom-up (TNO_newRWC = REF2) more or less consistent (Germany higher % modern stoves)
- Even after >5 years the crude approach (grey bars) is surpsingly in line with country estimates if they include CPM but we may be able to do better now taking up the results of last years (not funded, slow progress)

DEVELOPMENTS IN EMISSION REPORTING

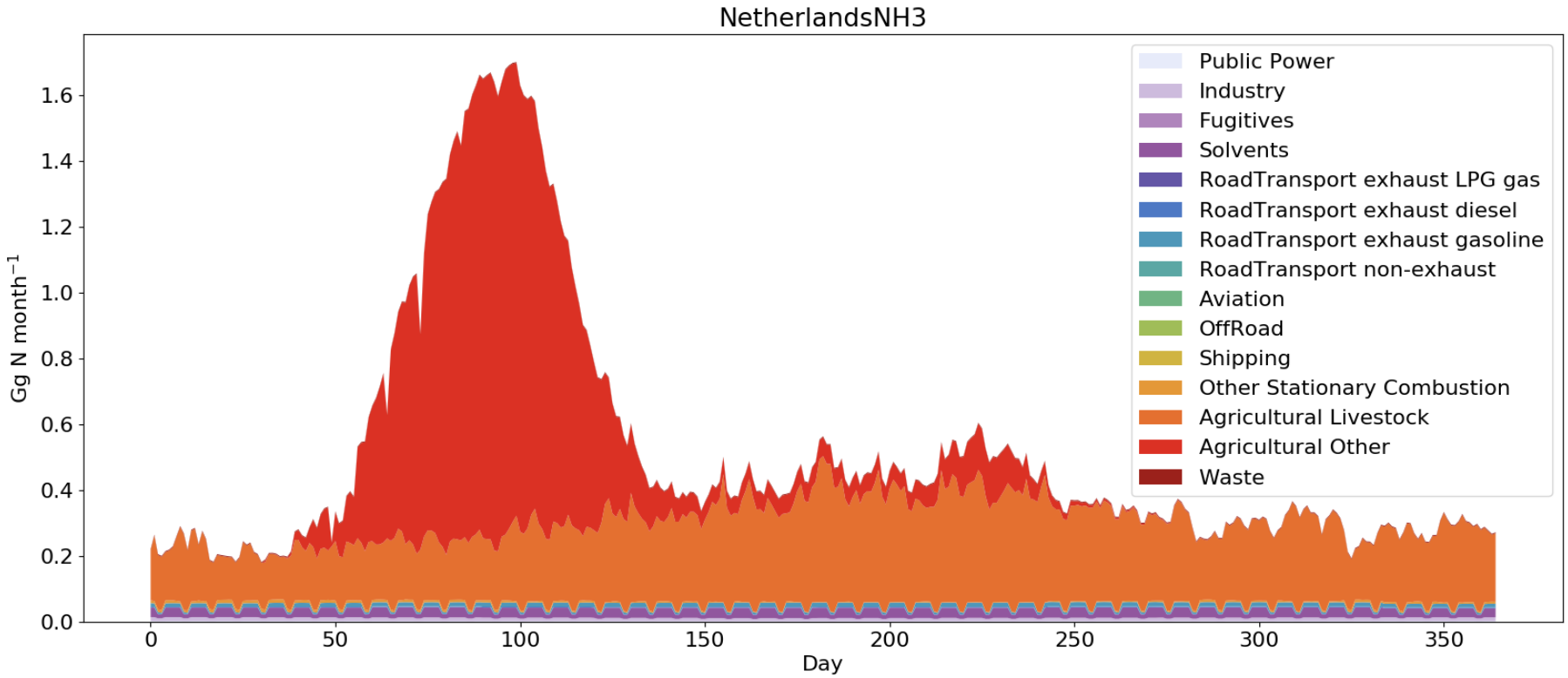


EMISSION TIMING

- From Emission Inventories to Emission Modelling
  - Model temporal (and spatial) variation according to real-time parameters
    - Meteorology dependent emissions (e.g. temperature dependency in household heating and agriculture)
    - Actual traffic flows, impacts of holidays, etc.



EMISSION TIMING (CONT'D)

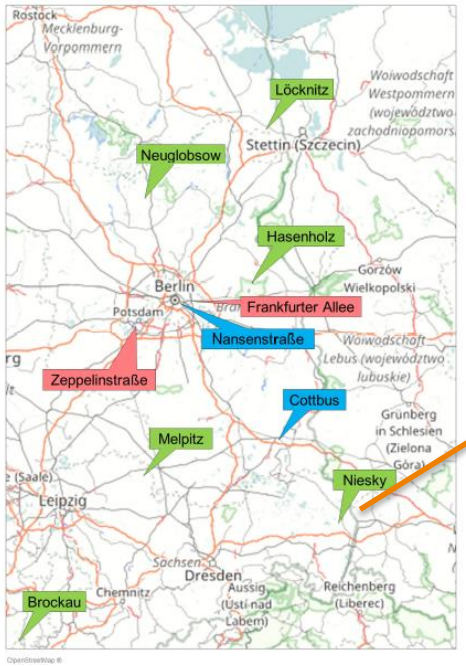


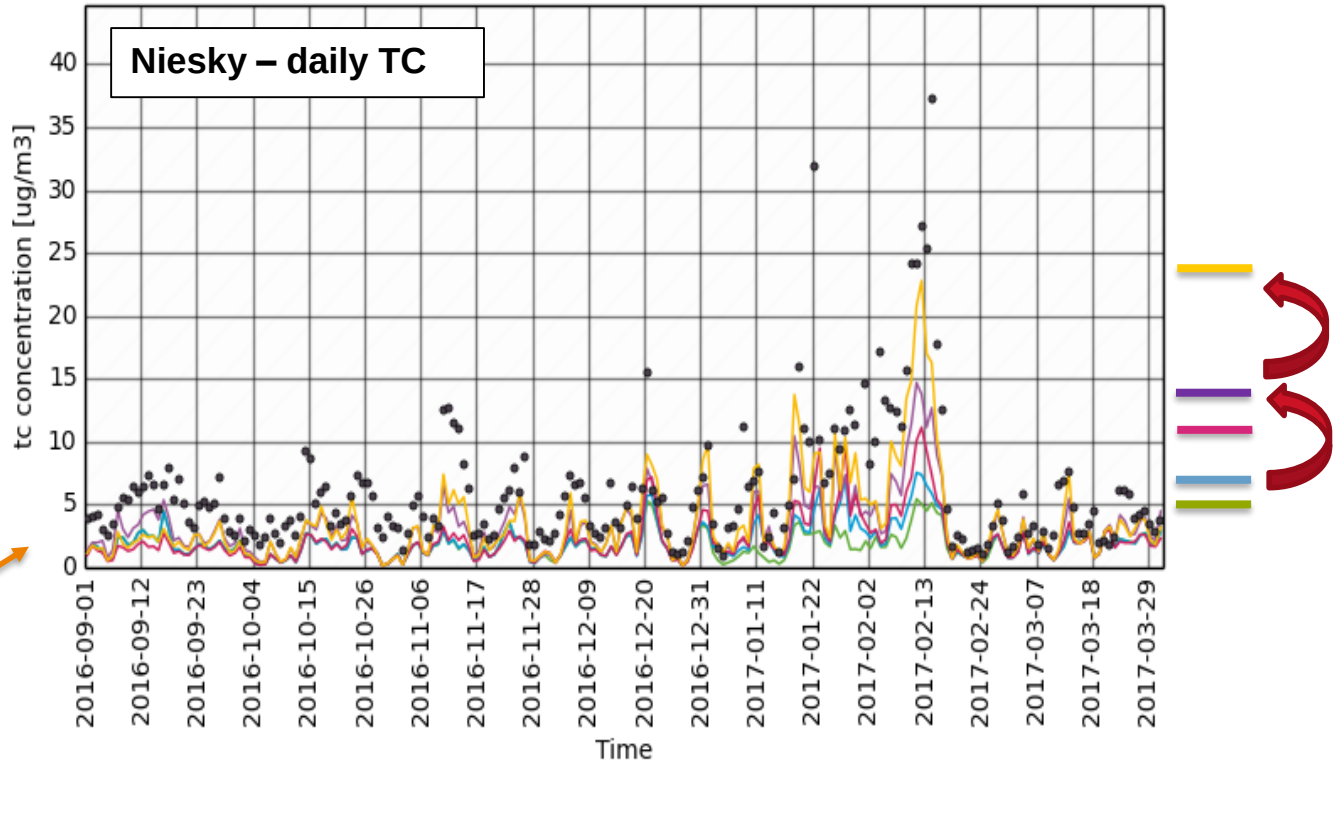
Agricultural distribution based on Skjøth et al. 2011 (ACP)

IMPACT ON MODELLING RESULTS

LOTOS-EUROS model over Germany using different emissions/options

- RWC = using TNO bottom-up inventory for residential combustion instead of base emissions
- Heating = using HDD approach for emission timing instead of default profile





CONCLUSIONS

- CAMS emission inventories provide an improved & updated starting point for emissions at European scale as input to modellers
  - Taking into account latest available knowledge from country inventories (NFR tables), with the possibility to replace/correct as necessary
  - Time series 2000-2015 and year 2016 (single year) publicly available
  - Time series 2000-2017 just finalised, now under evaluation

- What we see in reported emissions
  - Consistency and completeness across time series clearly improves
  - 0.1°x0.1° reporting of gridded data is well established in many countries, but lacking in some others
  - Recalculations from one year to the next can be very large!
  - Some sources not (consistently) addressed (agriculture, small comb.)

These are key issues for users!


THANK YOU FOR YOUR ATTENTION
Take a look:
TNO.NL/TNO-INSIGHTS
TNO innovation for life