Earth Observation Emissions of NOx, NH3 and BVOC from SEEDS available for benchmarking

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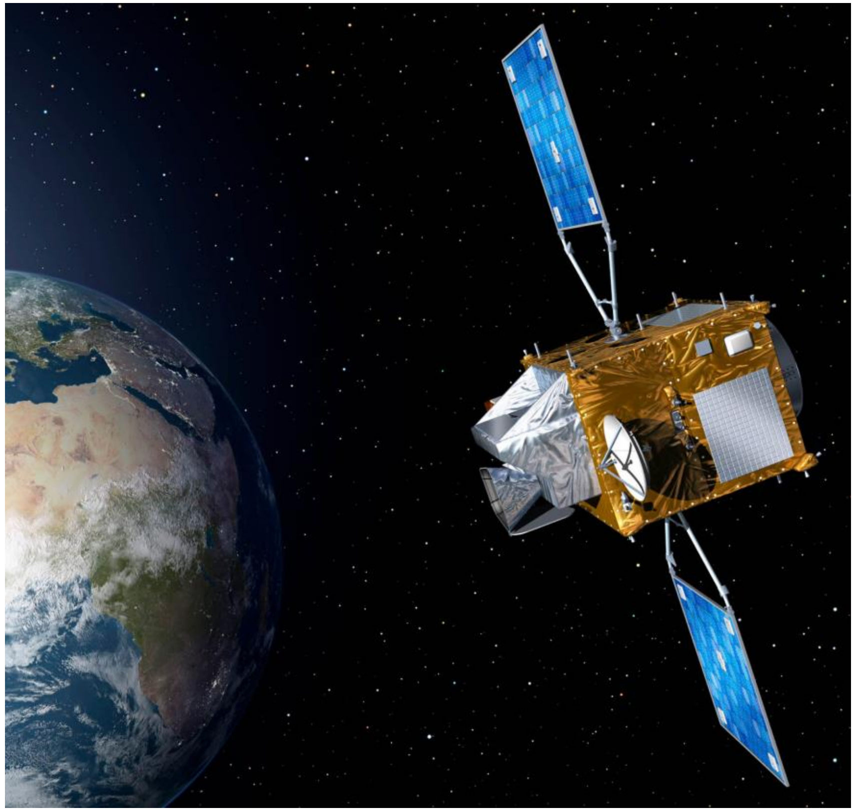
Funded by the European Union

SEEDS – H2020 project

Sentinel EO-based Emission and Deposition Service

SEEDS
Sentinel EO-based Emission and Deposition Service



- The SEEDS project goal is to develop several top-down (satellite) inversion techniques to estimate European emissions of NOx, NH3, VOC, improve deposition flux modelling and develop advanced data assimilation techniques.
- The project is developing techniques that may eventually become part of the Copernicus Atmosphere Service (CAMS).
- SEEDS is now entering its third and final year and we have begun to compile a significant number of datasets in our portal for further evaluation.

Sentinel 5P & Preparation for Sentinel 4

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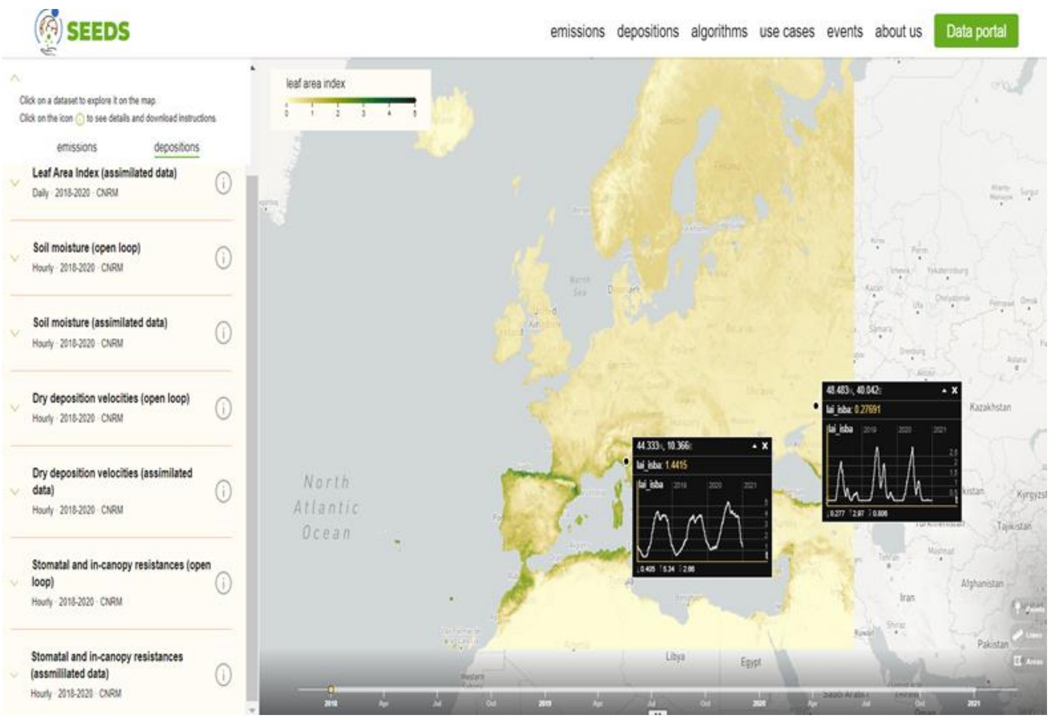
SEEDS – New Products



https://www.seedsproject.eu/data

SEEDS uses inverse modelling to produce up-to-date high-resolution estimates of NOx, NH_3 and biomass burning emissions.

- **NOx** – 2019,2020 -2022 Monthly anthropogenic NOx emissions at up to 5 km resolution
- **NH_3** – 2019, 2020 -2022 Monthly NH_3 emissions with 20 km resolution
- **Fires** - 2018-2020 -2022 Monthly biomass burning emissions at up to 10 km resolution
- **Soil NOx** – 2019, 2020 -2022 Agricultural soil NOx emissions at up to 5 km resolution
- **BVOC** -2019, 2020-2022 Top-down and bottom-up estimates of Biogenic Organic Compounds with 10 km resolution
- **LAI** - 2018-2020 -2022 Leaf area index data sets at 10 km spatial resolution
- **Soil Moisture** – 2018- 2020 -2022 Soil moisture datasets at 10 km spatial resolution
- **Deposition** - 2018-2020, -2022 Deposition fluxes and diagnostics (e.g., stomatal resistance) for ozone and nitrogen at 10 km spatial resolution

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Waters

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SEEDS – H2020 project
Sentinel EO-based Emission and Deposition Service

SEEDS
Sentinel EO-based Emission and Deposition Service

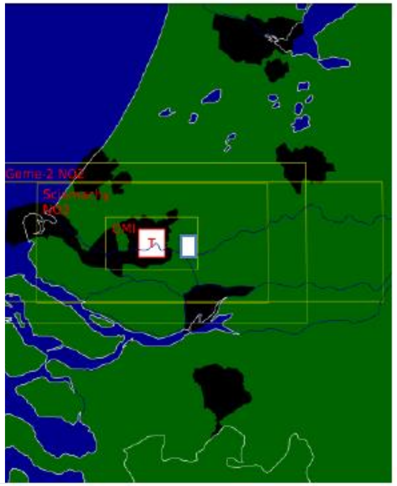
What makes TROPOMI unique?

TROPOMI combines 4 unique features:

Large spectra range
(large # of trace gas species)
High signal-to-noise

High spatial resolution
(3.5 x 5.5 km)

Daily global coverage



TROPOMI Operational Data products

Product	Application
Ozone	Ozone layer monitoring, UV-index forecast, Climate monitoring
NO_2	Air quality forecast and monitoring ← SEEDS
CO	Air quality forecast and monitoring
CH_2O	Air quality forecast and monitoring ← SEEDS
CH_4	Climate monitoring
SO_2	Air quality forecast and monitoring, Climate monitoring, Volcanic plume detection
Aerosol	Air quality forecast and monitoring, Climate monitoring, Volcanic plume detection
Clouds	Climate monitoring
UV-Index	UV index forecast

KNMI | DLR | BIRA-IASB | SRON | RAL |IUP-Bremen | MPIC | FMI | ESA

Development of supplementary products: SIF, AOD, CHOCHO, HONO, ALH

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DECSO (Daily Emission estimates Constrained by Satellite Observation)

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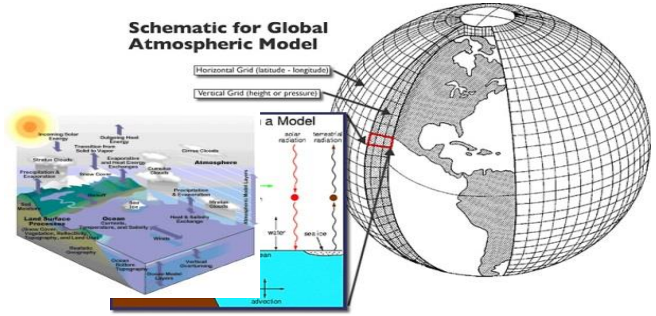
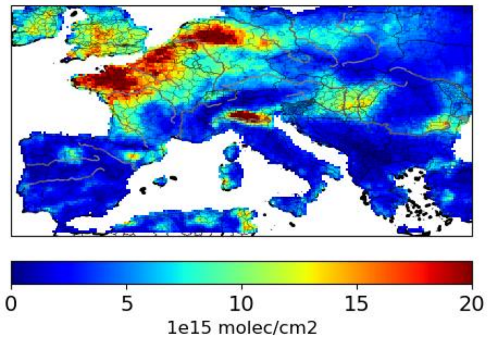
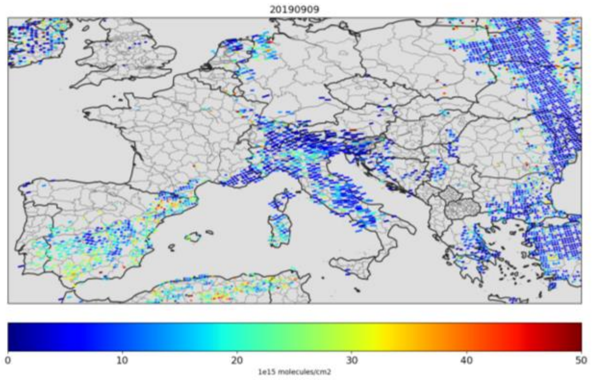
SEEDS inversion of satellite observations for NOX and NH3 based on DECSO (KMNI)

Chemistry Transport Model - Chimere

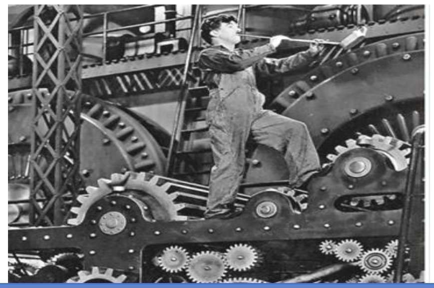


Concentrations



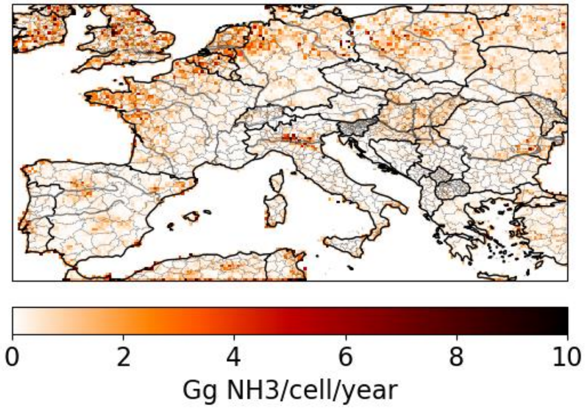


Satellite observations



State vector forecast	$\mathbf{x}^f(t_{i+1}) = M_i\,[\mathbf{x}^a(t_i)]$
Error covariance forecast	$\mathbf{P}^f(t_{i+1}) = \mathbf{M}_i\mathbf{P}^a(t_i)\mathbf{M}_i^T + \mathbf{Q}(t_i)$
Kalman gain matrix	$\mathbf{K}_i = \mathbf{P}^f(t_i)\mathbf{H}_i^T[\mathbf{H}_i\mathbf{P}^f(t_i)\mathbf{H}_i^T + \mathbf{R}_i]^{-1}$
State vector analysis	$\mathbf{x}^a(t_i) = \mathbf{x}^f(t_i) + \mathbf{K}_i(\mathbf{y}_i^o - H_i\,[\mathbf{x}^f(t_i)])$
Error covariance analysis	$\mathbf{P}^a(t_i) = (\mathbf{I} - \mathbf{K}_i\mathbf{H}_i)\,\mathbf{P}^f(t_i)$

Inversion algorithm



Emissions

NOx emissions - Regions at various resolutions

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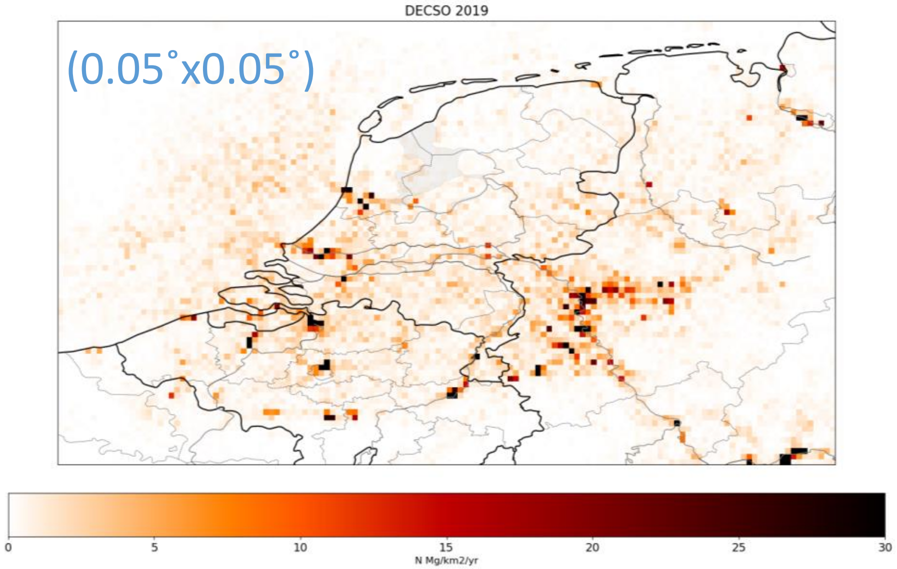
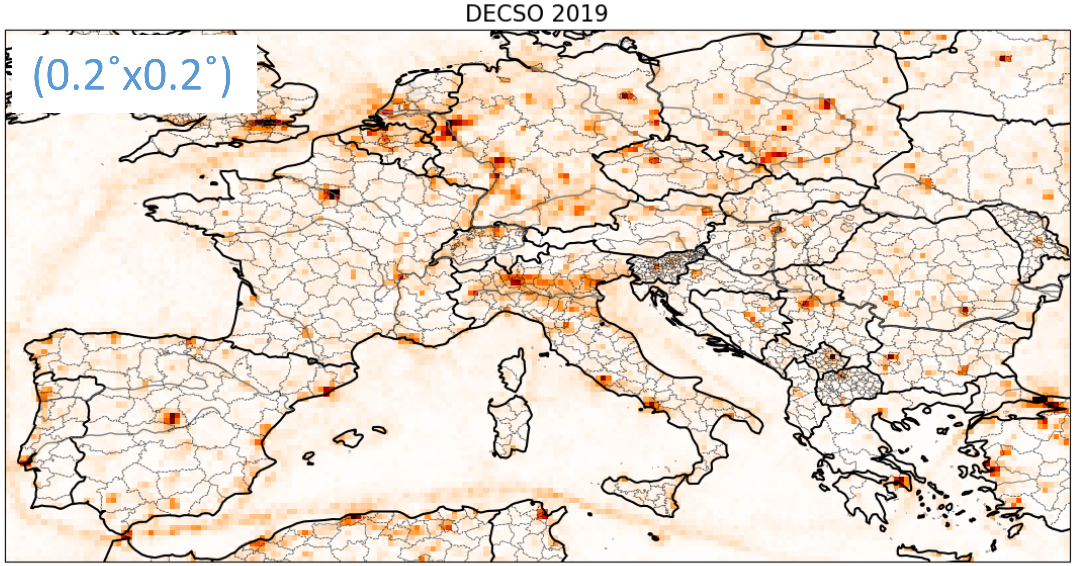
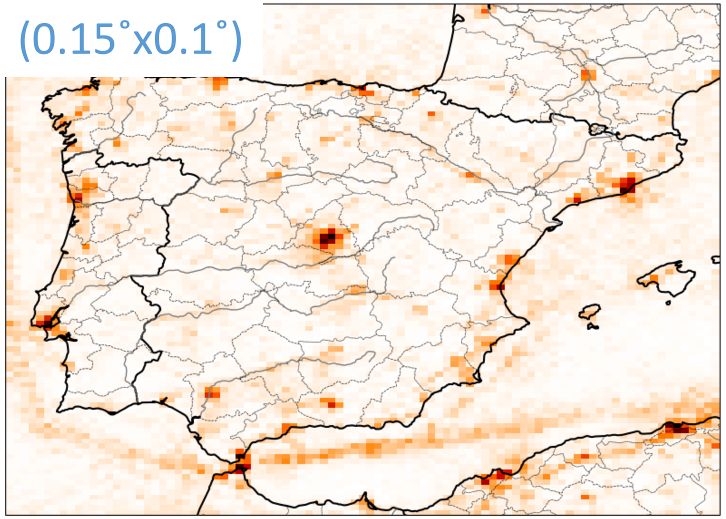
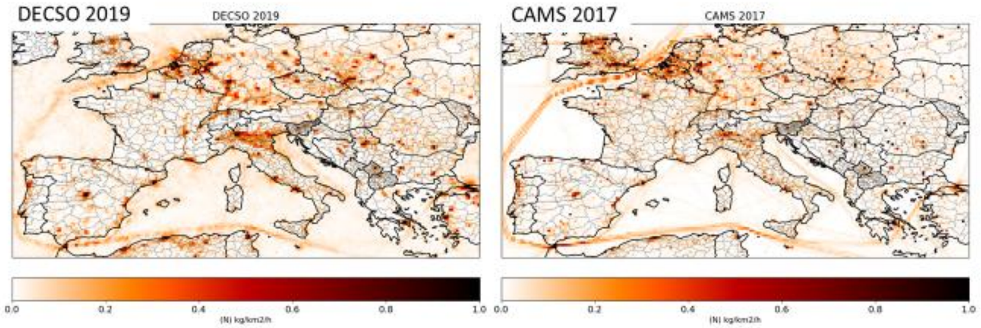




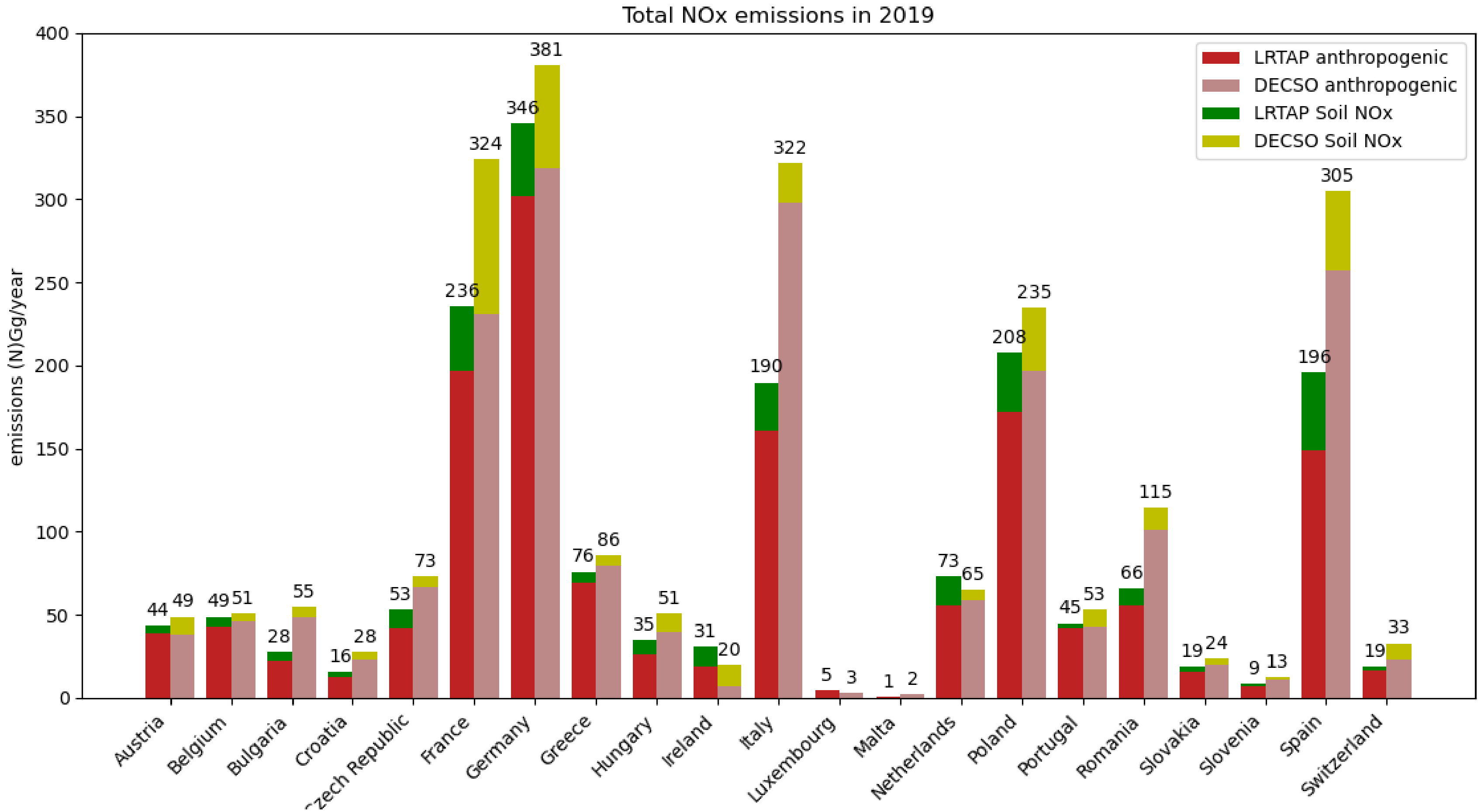


Comparison to CAMS emissions



Country totals of NOx vs. LRTAP

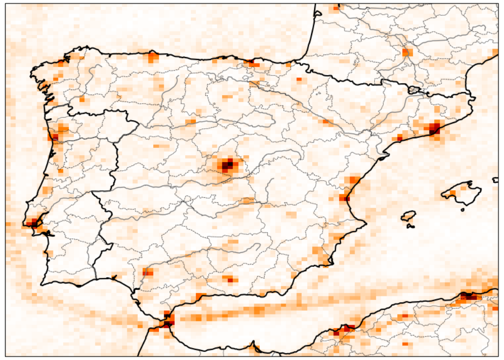
- DECSO: light color bars
- LRTAP (EEA): dark color bars



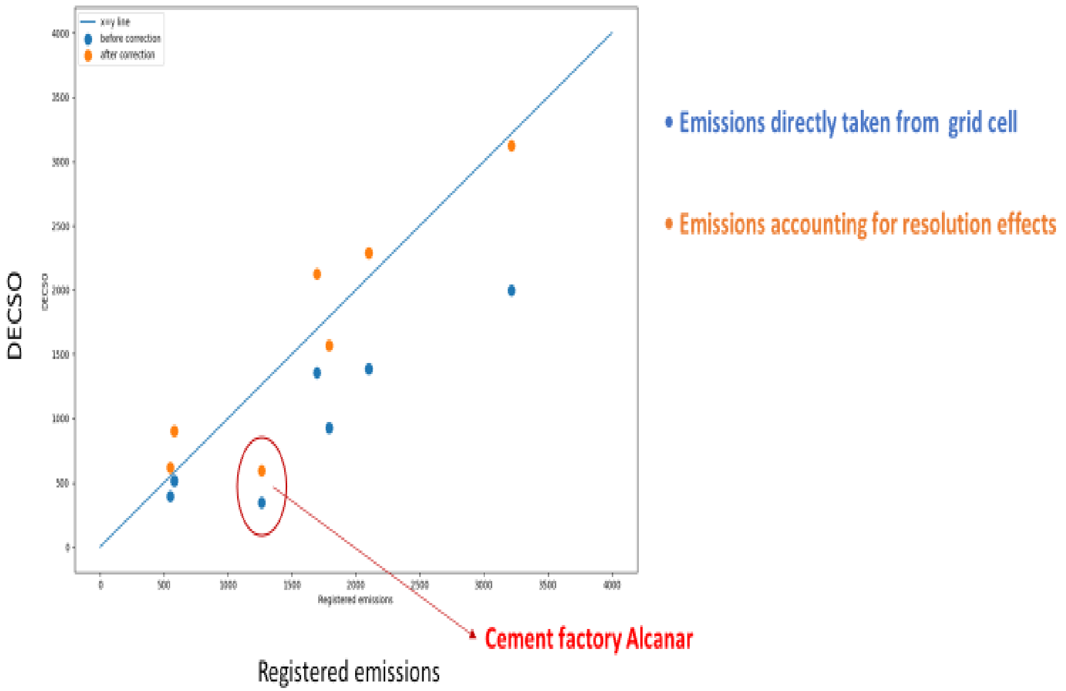
Point sources: Comparison with power plants and cement factories in Spain

Comparison for Spain

- DECSO derived at **0.1 x 0.15 degree**
- Point sources from **HERMES/E-PRTR**

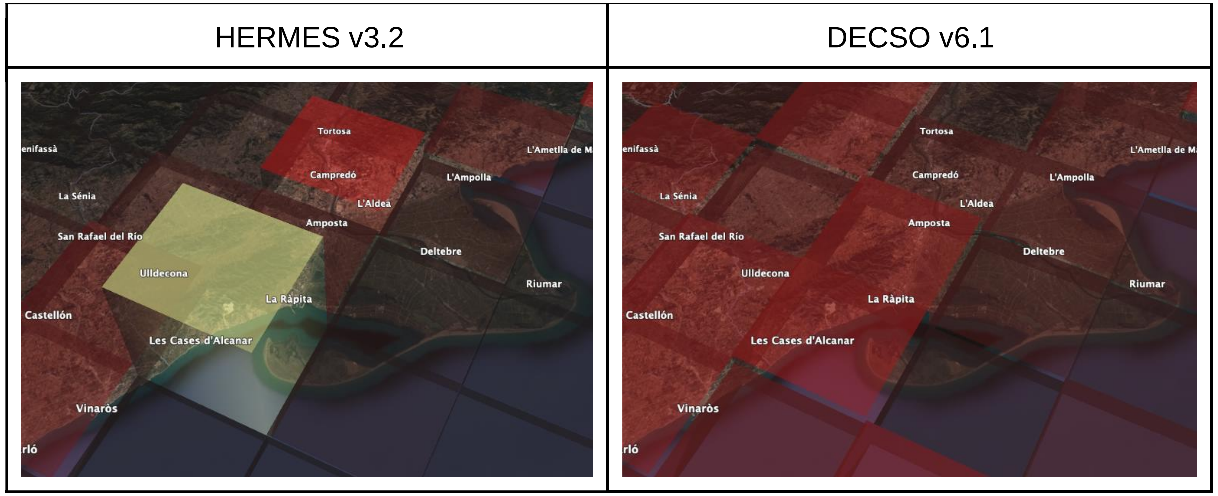


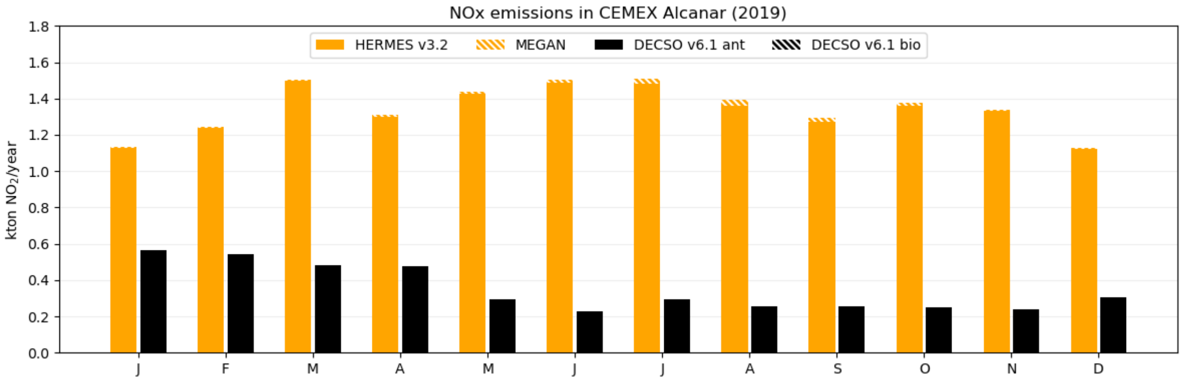
Identification of outliers : Comparison accounting for the resolution



Hotspot emissions HERMES [ton NO2/year]

Industrial hotspot in Alcanar





- A strong registered point source in HERMES (**1.33 kton NO2/year**) → emissions derived from the Large Point Source Database provided by the Spanish Ministry of Environment
- The DECSO estimation, however, is 74% lower: **0.35 kton NO2/year**
- Results from the Continuos Emission Monitoring System provided by the Government of Catalonia indicate emissions of **1.1kton NO2/year**
- The large disagreement is not well understood, and subject of further investigation (factory hotspot hardly visible in the level-2 TROPOMI satellite product, errors in the assumed surface albedo?)

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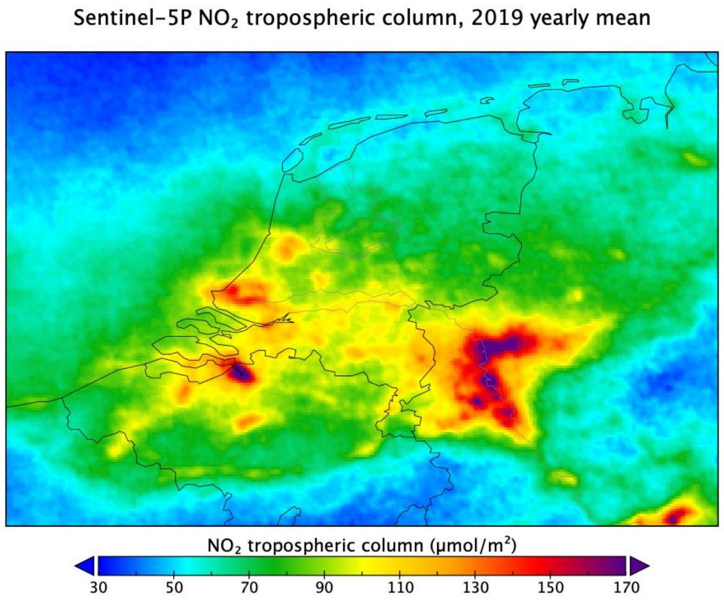
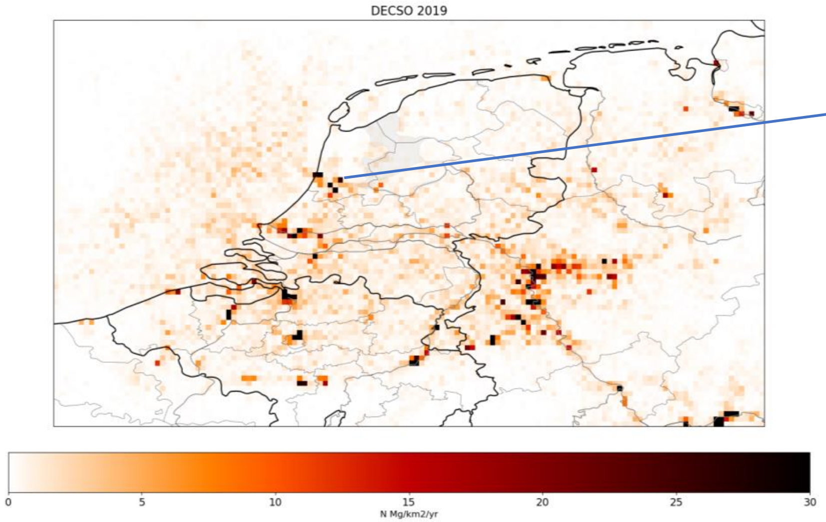
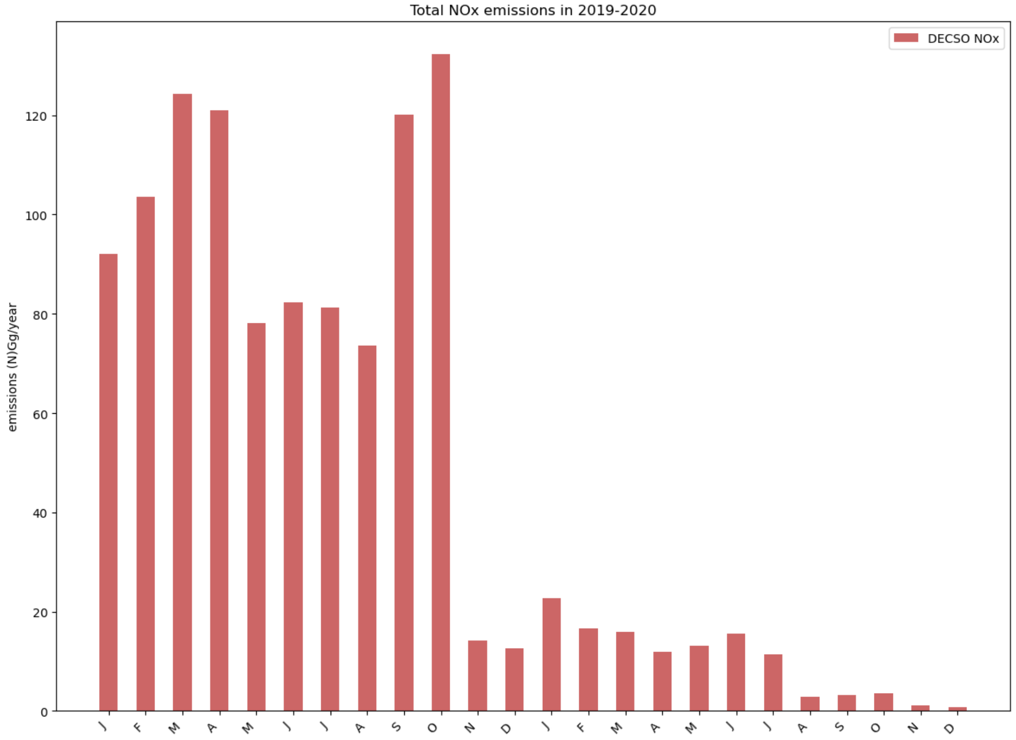
Timeseries checks with use of satellite data



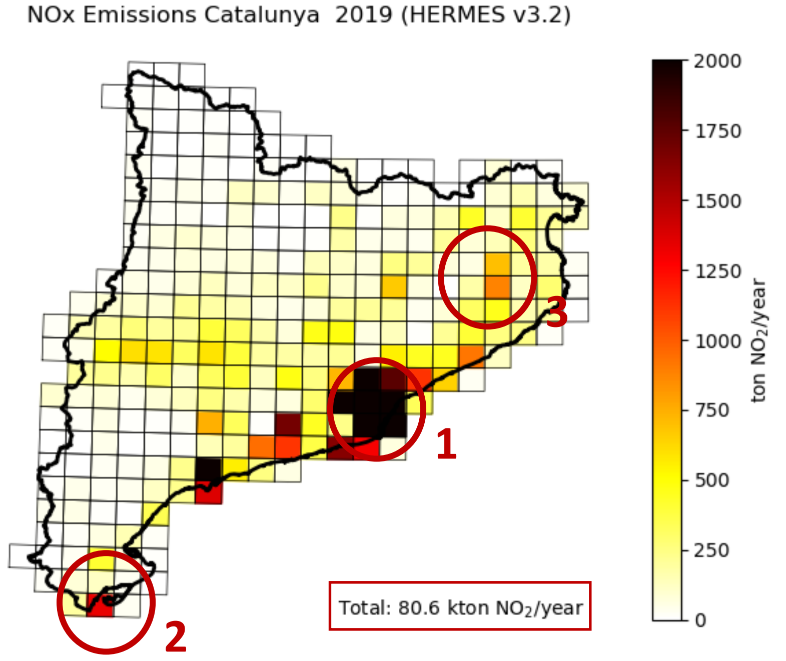


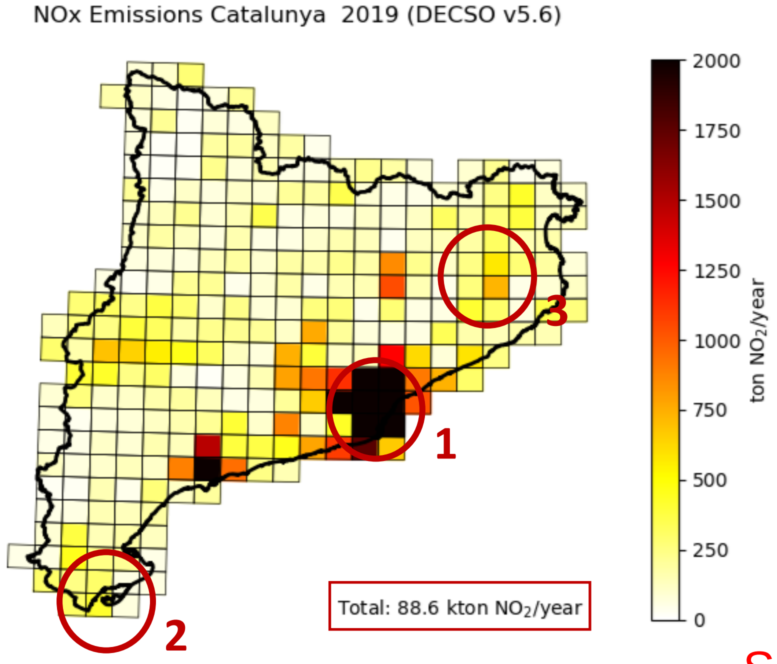
Going to a higher grid resolution: 3x5 km in the Netherlands

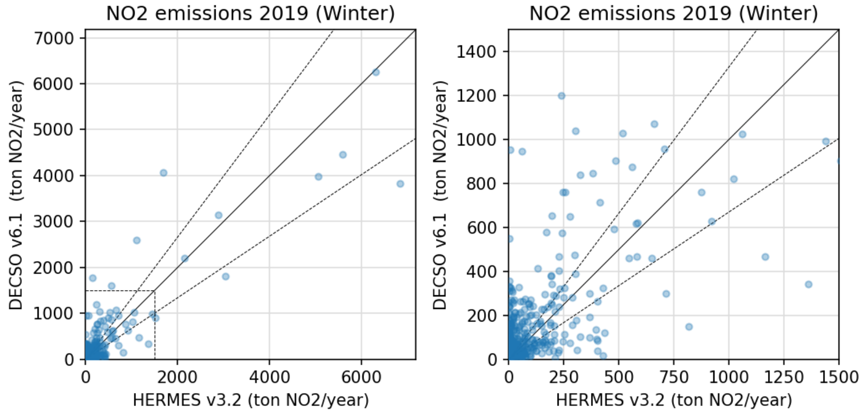
Powerplant “Hemweg centrale” decommissioned end of 2019



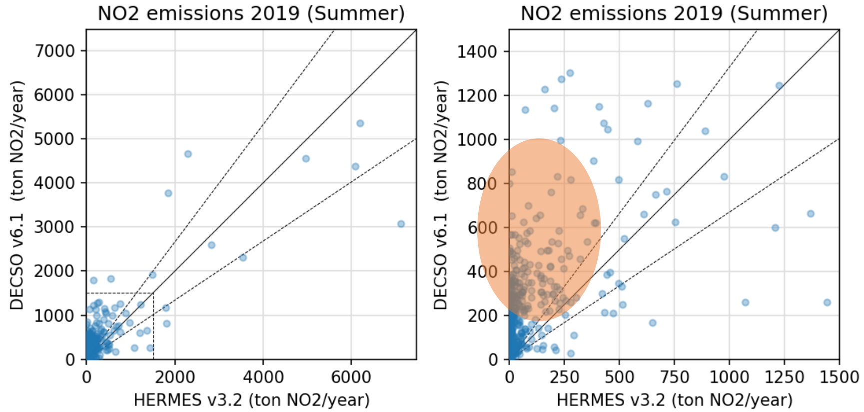
HERMESv3 versus DECSO







Soil NOx emissions



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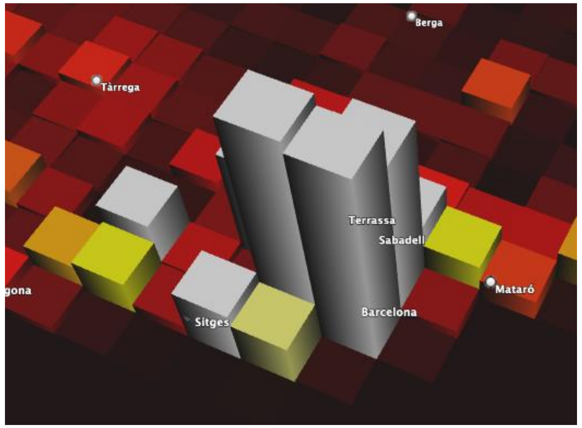
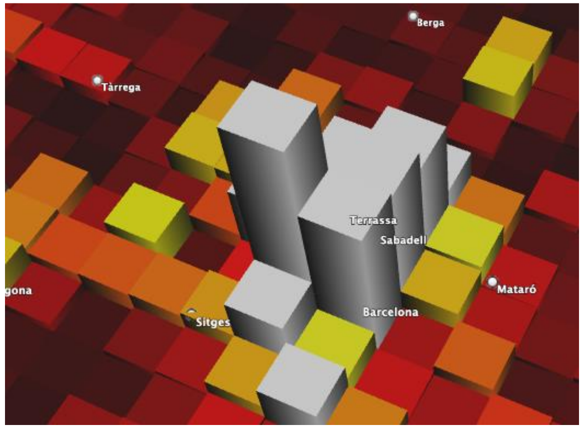
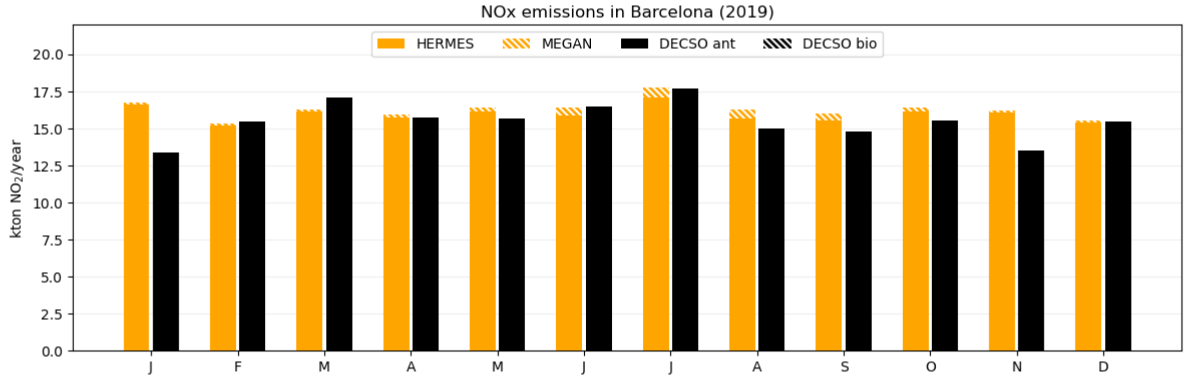
Comparisons for Nox emissions in Barcelona area

HERMES v3.2	DECSO v6.1
	



- 27.3 kton NO2/year according to HERMES, which is about 34% of the total emissions found in Catalunya.
- DECSO estimates slightly less NOx emissions for this area: 26.1 kton NO2/year.
- Although differently distributed over the grid cells, the aggregated emissions are well in line.
- No strong seasonalities identified neither in HERMES nor DECSO

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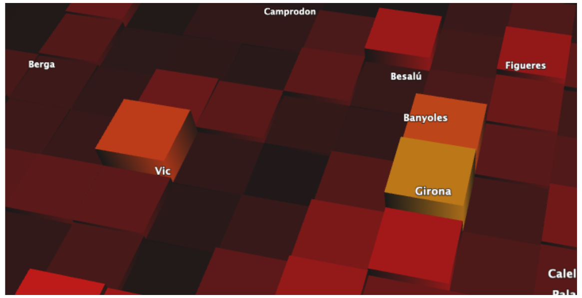
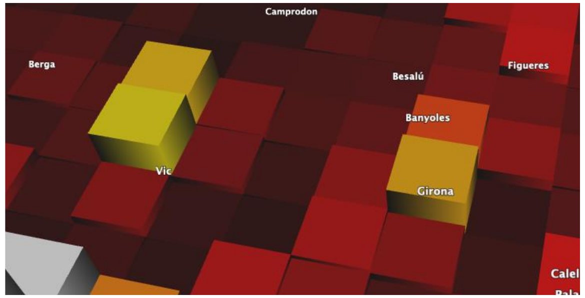
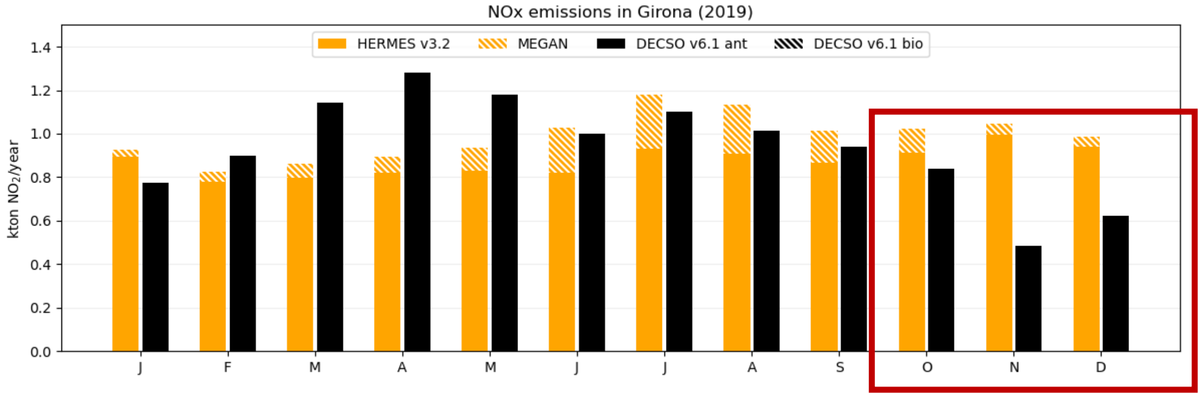
Comparison for Nox emissions in Girona area

HERMES v3.2



DECSO v6.1





- Results in total annual emissions agree very well, with HERMES having slightly stronger emissions.
- Important differences in the seasonal cycle: DECSO shows a continuous decrease during OND, while HERMES mantains almost constant emissions
- Influence of emissions from agricultural machinery and associated crop calendar considered in HERMES

Crop type	Soil cultivation	
	Start_date	End_date
Wheat	1st November	31st December
Rye	1st September	31st October
Barley	1st November	31st December
Oat	1st October	31st November

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Ammonia emissions in SEEDS

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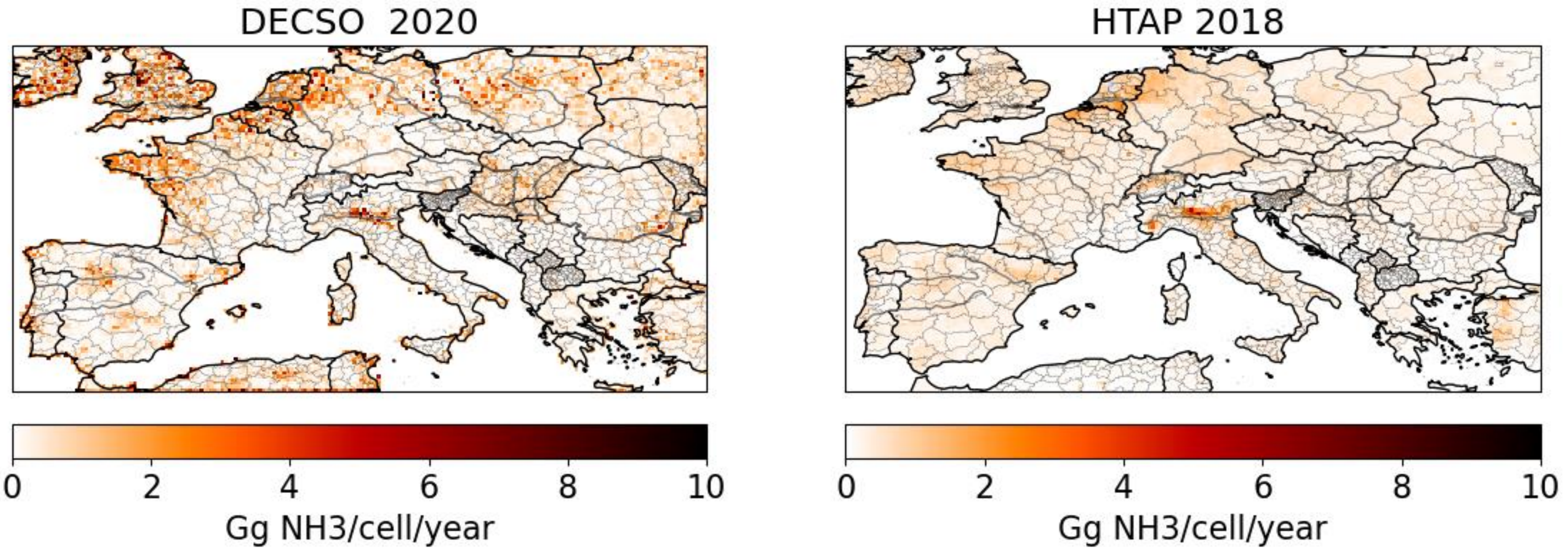
Emission estimation method:

Inversion technique using satellite observations and a chemical transport model:

DECSO (see presentation from Ronald van der A)

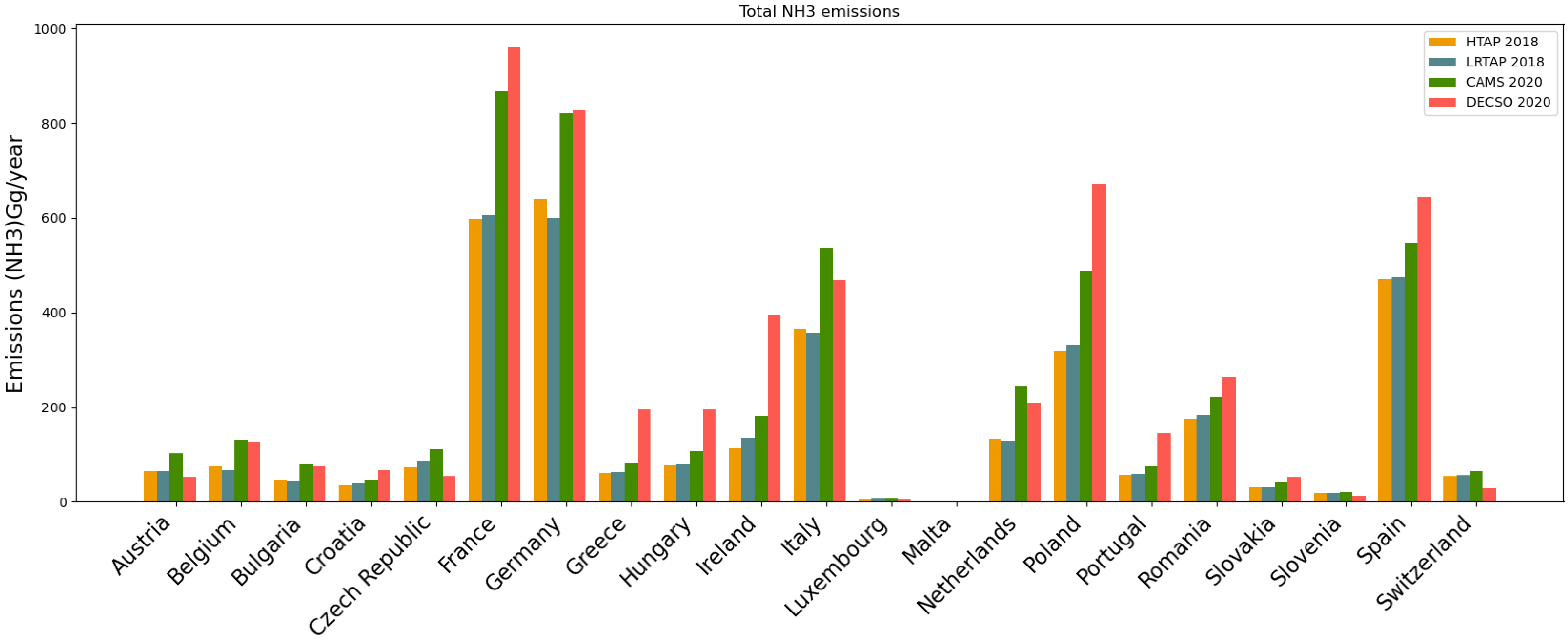
Products:

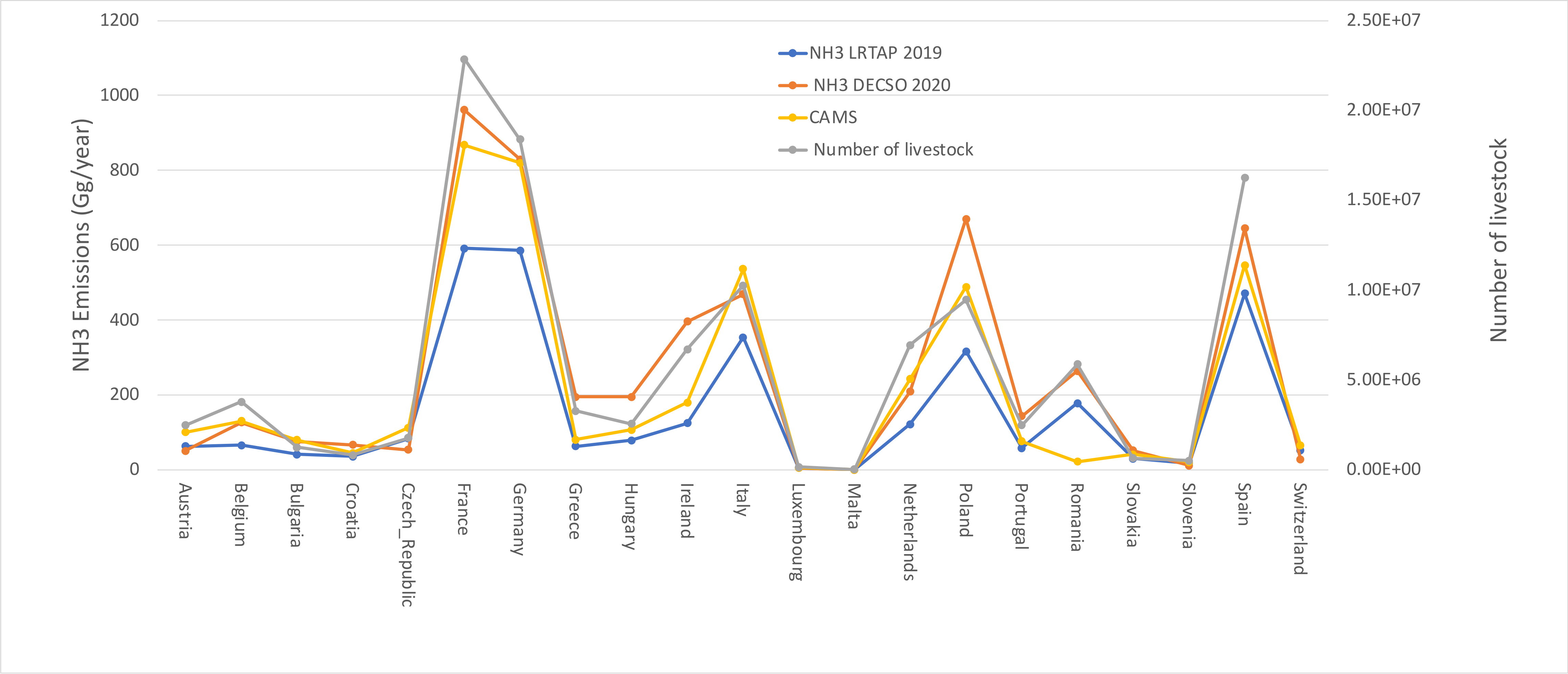
NH3 emissions from CRIS



The ammonia emissions spatial distribution

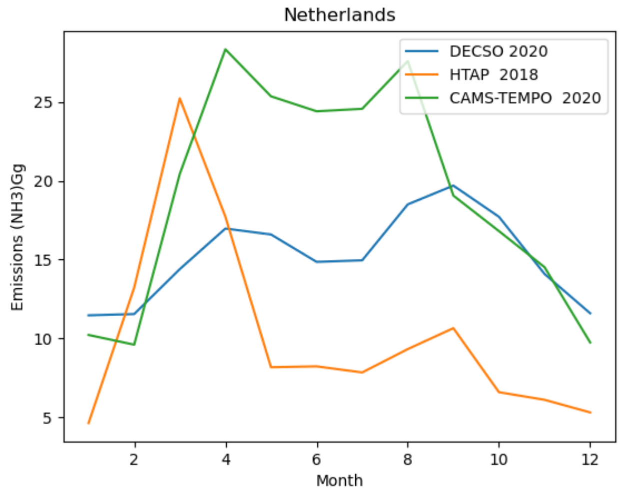
Comparison of country totals top-down vs bottom-up

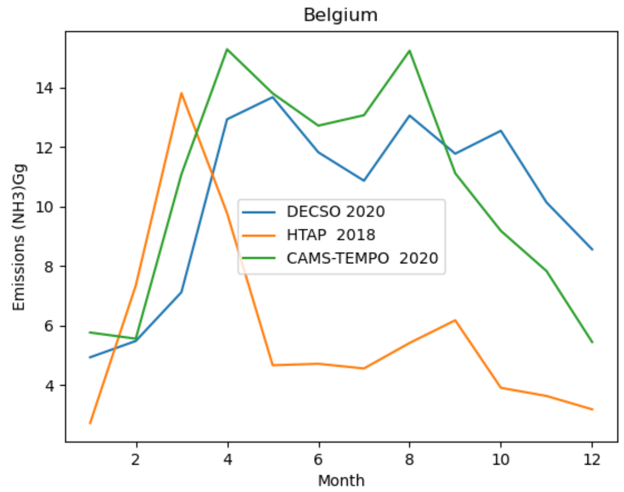


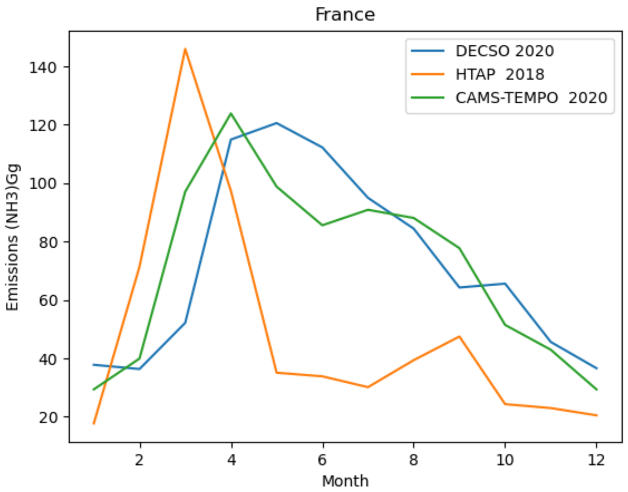


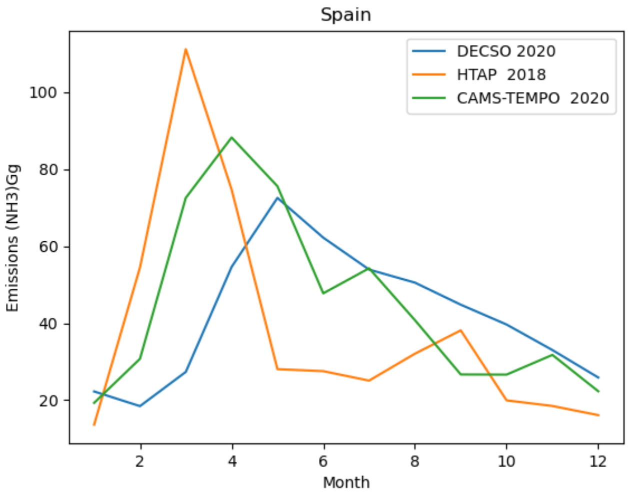
NH3 LRTAP 2019
NH3 DECSO 2020
CAMS
Number of livestock
NH3 Emissions (Gg/year)
Number of livestock
1200
1000
800
600
400
200
0
2.50E+07
2.00E+07
1.50E+07
1.00E+07
5.00E+06
0.00E+00
Austria
Belgium
Bulgaria
Croatia
Czech_Republic
France
Germany
Greece
Hungary
Ireland
Italy
Luxembourg
Malta
Netherlands
Poland
Portugal
Romania
Slovakia
Slovenia
Spain
Switzerland

Monthly variations

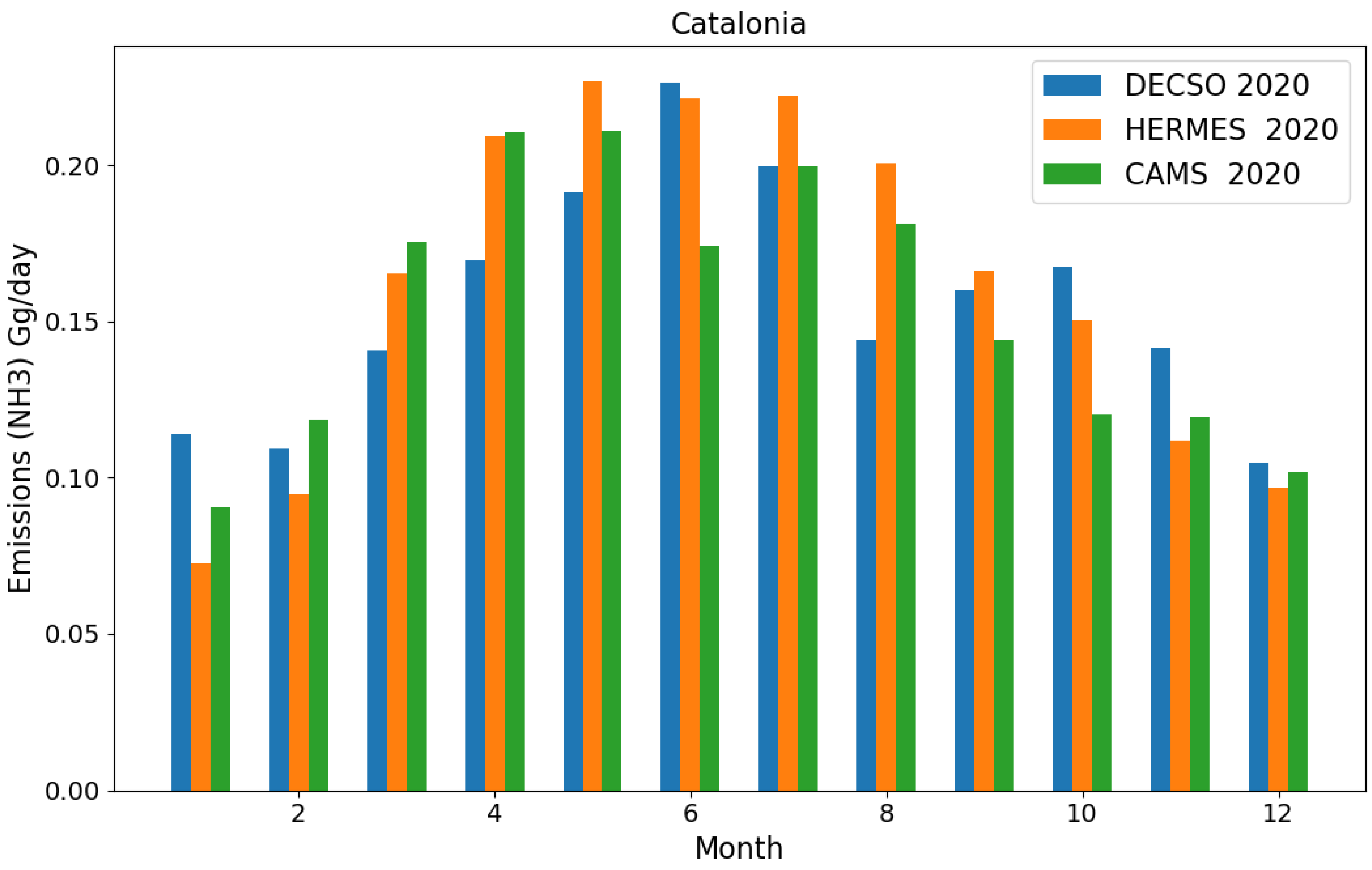




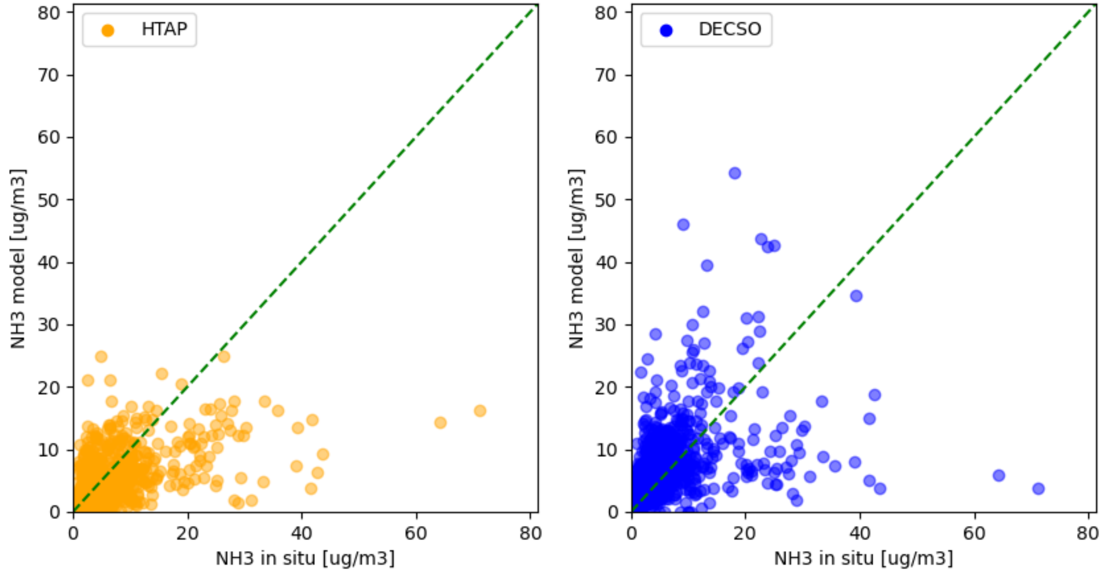




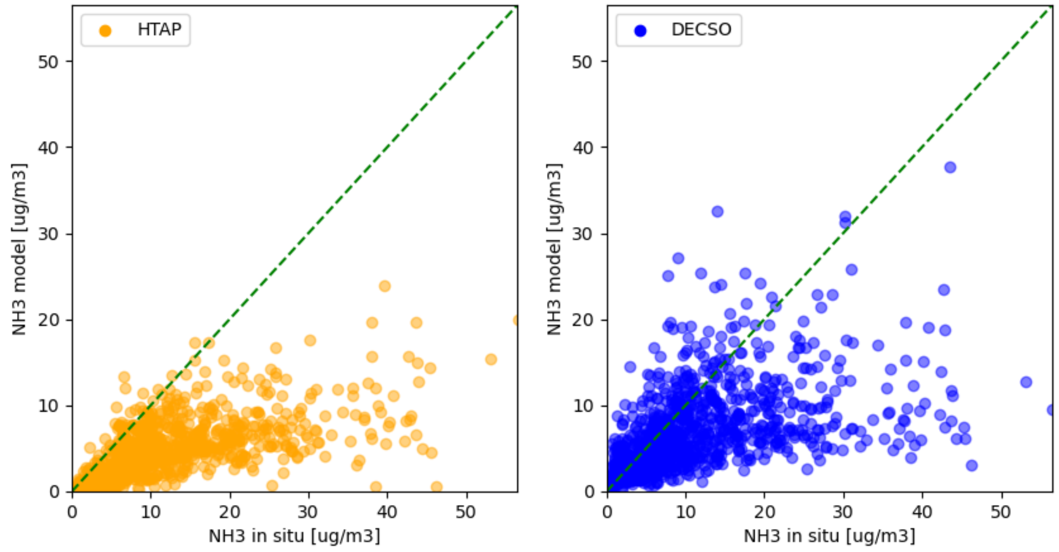
Monthly variations – Benchmarking in Catalonia



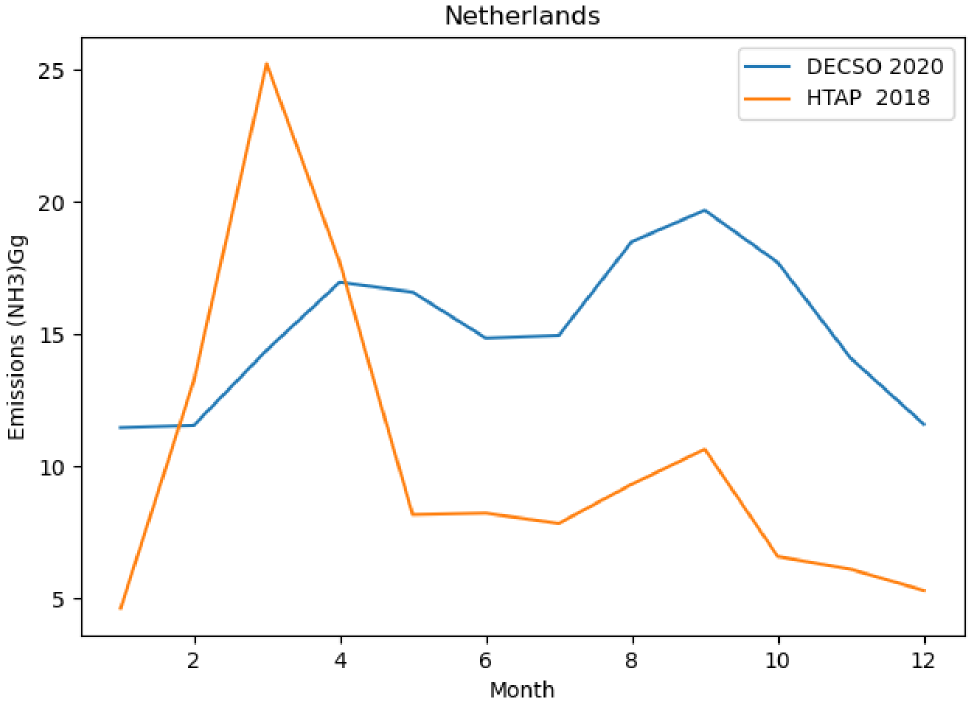
Winter months



Summer months



Benchmarking in the Netherlands



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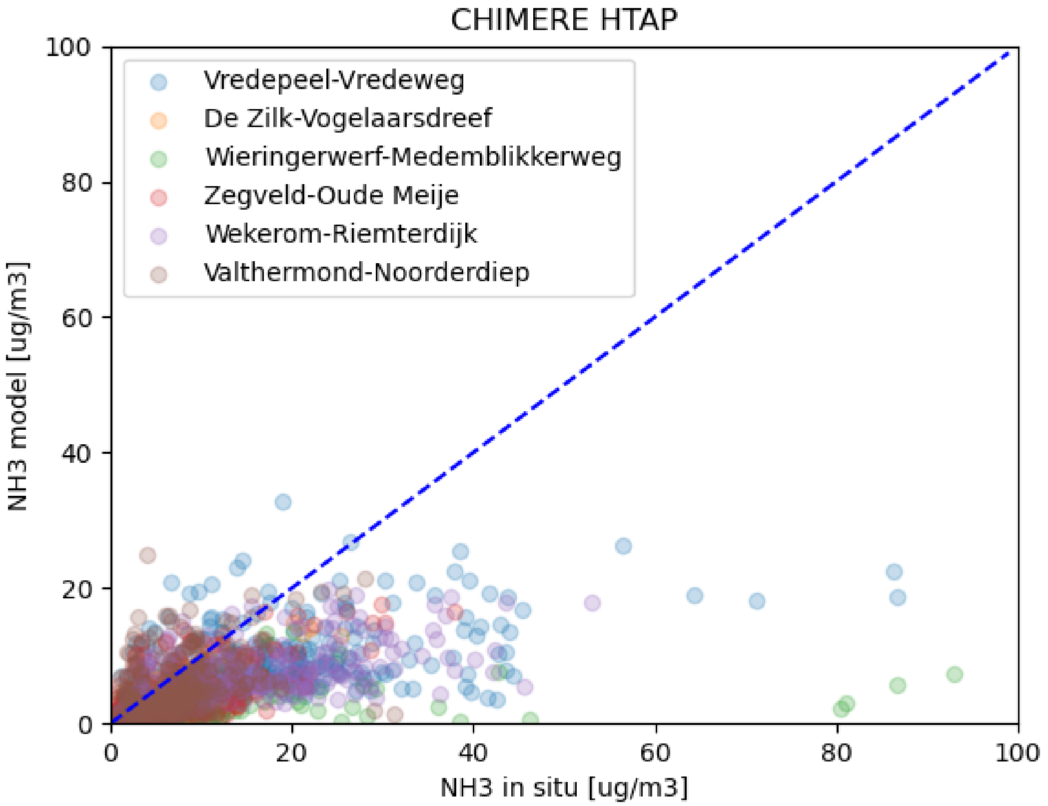
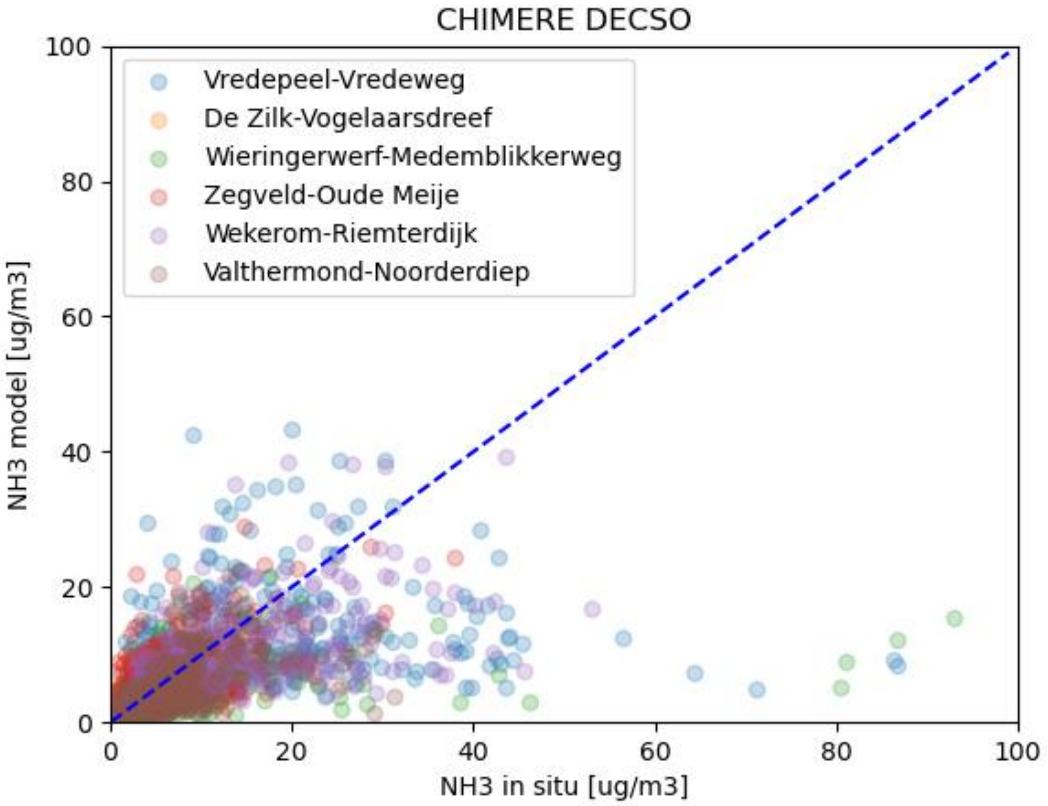
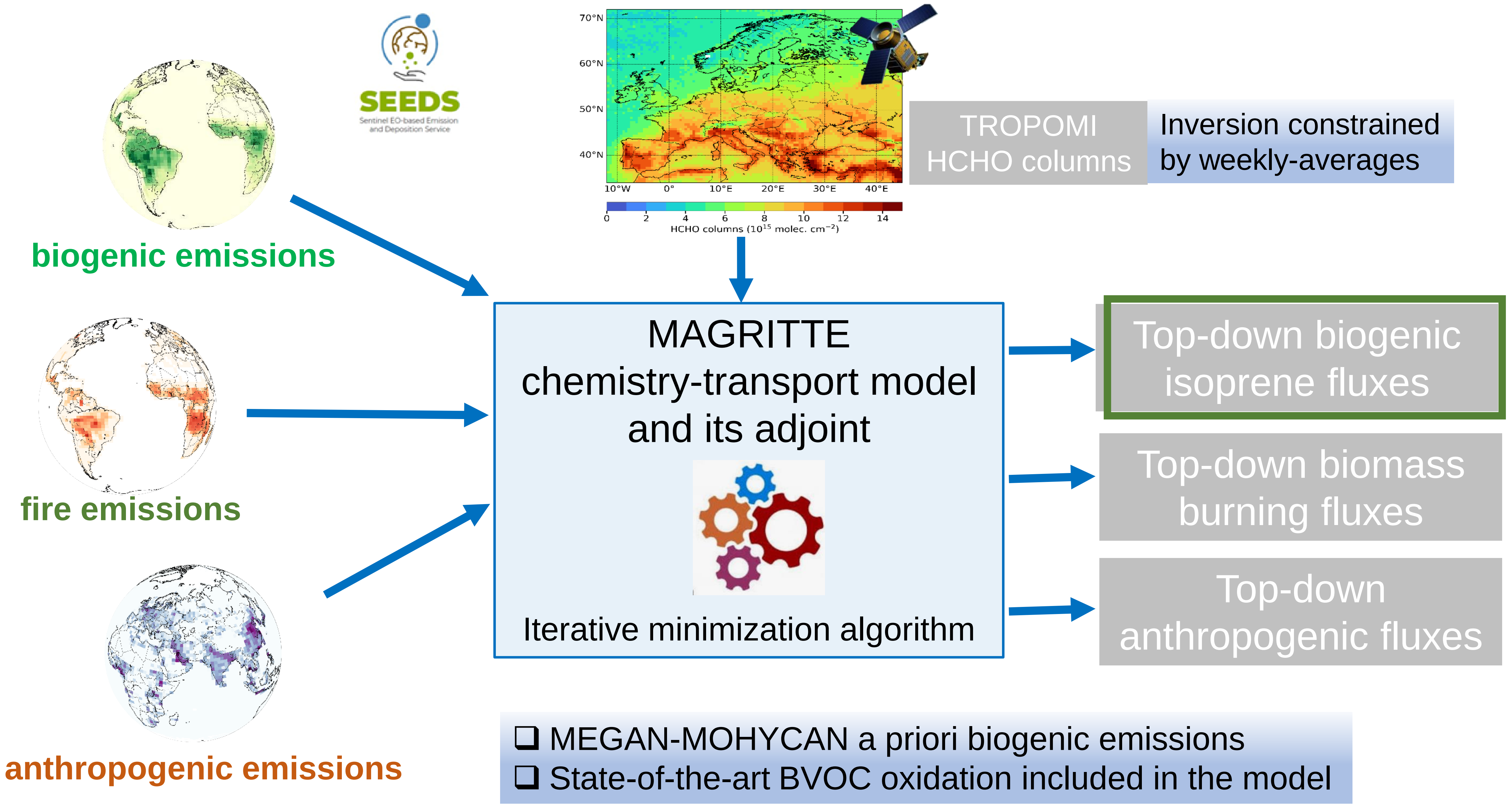
Model simulations vs In-situ measurements Netherlands

CHIMERE model simulations
Emissions: HTAP vs DECSO






SEEDS
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70°N
60°N
50°N
40°N
10°W
0°
10°E
20°E
30°E
40°E
0
2
4
6
8
10
12
14
HCHO columns (10^{15} molec. cm^{-2})
TROPOMI HCHO columns
Inversion constrained by weekly-averages
biogenic emissions
fire emissions
anthropogenic emissions
MAGRITTE chemistry-transport model and its adjoint
Iterative minimization algorithm
Top-down biogenic isoprene fluxes
Top-down biomass burning fluxes
Top-down anthropogenic fluxes
❑ MEGAN-MOHYCAN a priori biogenic emissions
❑ State-of-the-art BVOC oxidation included in the model

Formaldehyde columns in summer over Europe

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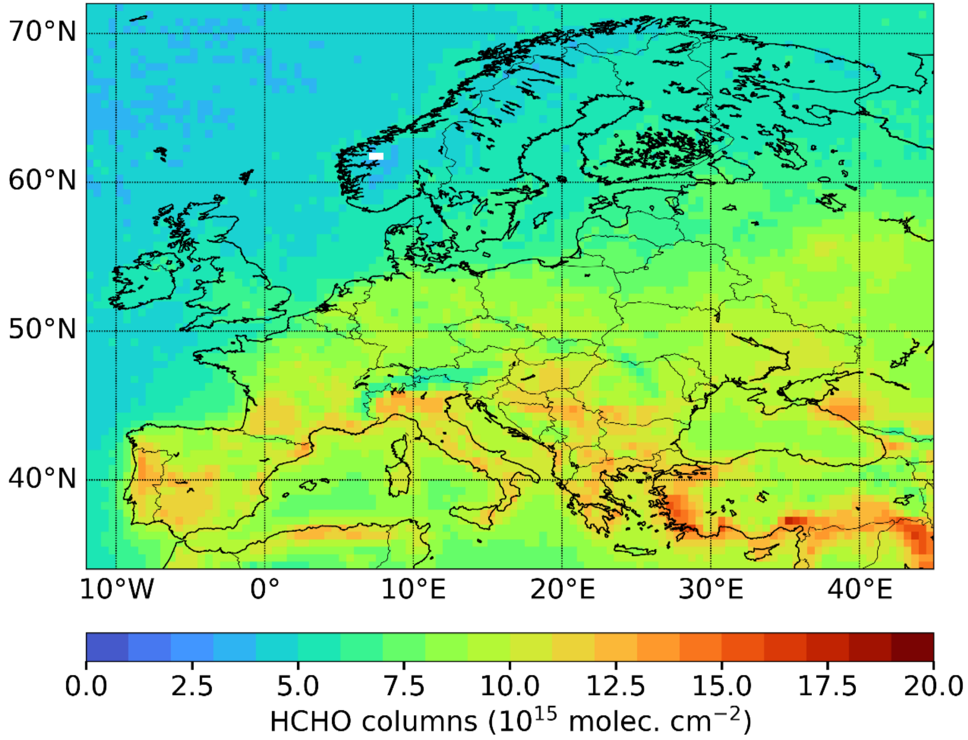
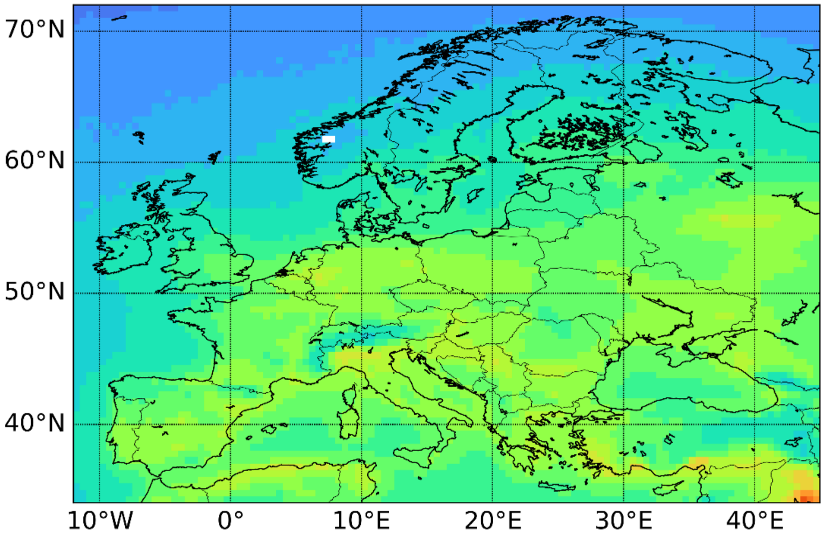
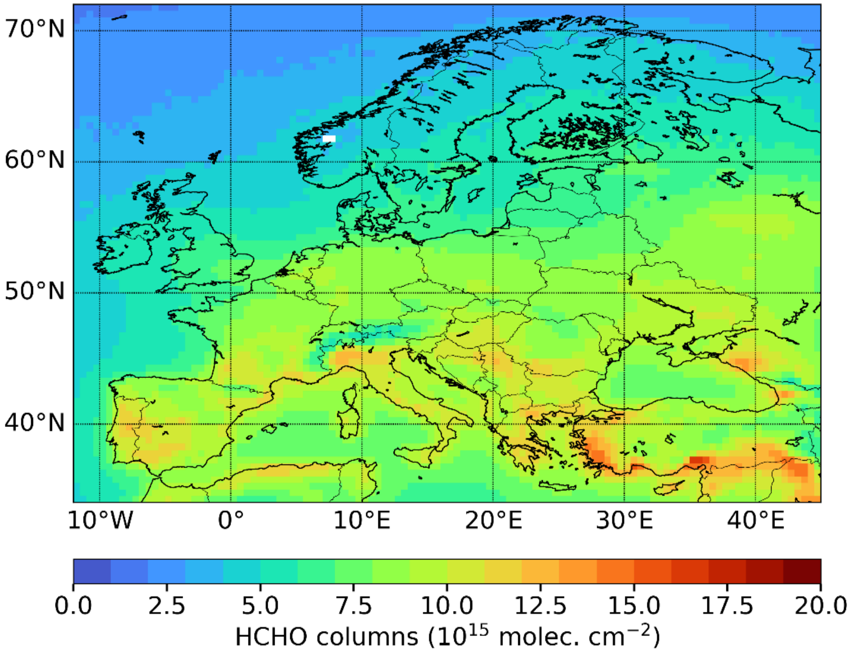
TROPOMI (observed)



MAGRITTE model (a priori)



MAGRITTE model (optimized)



Summary

- Both the "bottom-up community" can learn from the top-down results, and the "top-down community" can learn from the bottom-up results
- Top-down emissions estimates can be useful to **identify emission outliers,** such as for example the industrial facility in Alcanar, which appears a strong hotspot in HERMES, is largely unnoticed by DECSO (need further investigation)
- Top-down estimates with the current capabilities of satellite information, can also be helpful **for timeseries checks - year –to-year variations, monthly variations- weekly variations**
- DECSO highlights important role of biogenic Nox soil emission (specially in summer)
- The NH_3 and NOx emissions from DECSO are comparable with bottom-up emissions/ reported emissions for country totals. The spatial distribution of NH_3 and NOx emissions from DECSO is reasonable. Added value in the seasonality of the results
- We are looking for voluntaries to benchmark the SEEDS emissions products, including BVOC - Interested ? Contact lta@nilu.no