SEEDS
Sentinel EO-based Emission and Deposition Service

Funded by the European Union

Perspectives on the use of satellite data for emission evaluation: Conclusions from the SEEDS project

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TFEIP 2024 meeting – 16th May 2024

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Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Waters
BIRA-IASB
CERFACS
CENTRE EUROPÉEN DE RECHERCHE ET DE FORMATION AVANCÉE EN CALCUL SCIENTIFIQUE
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SEEDS – H2020 project

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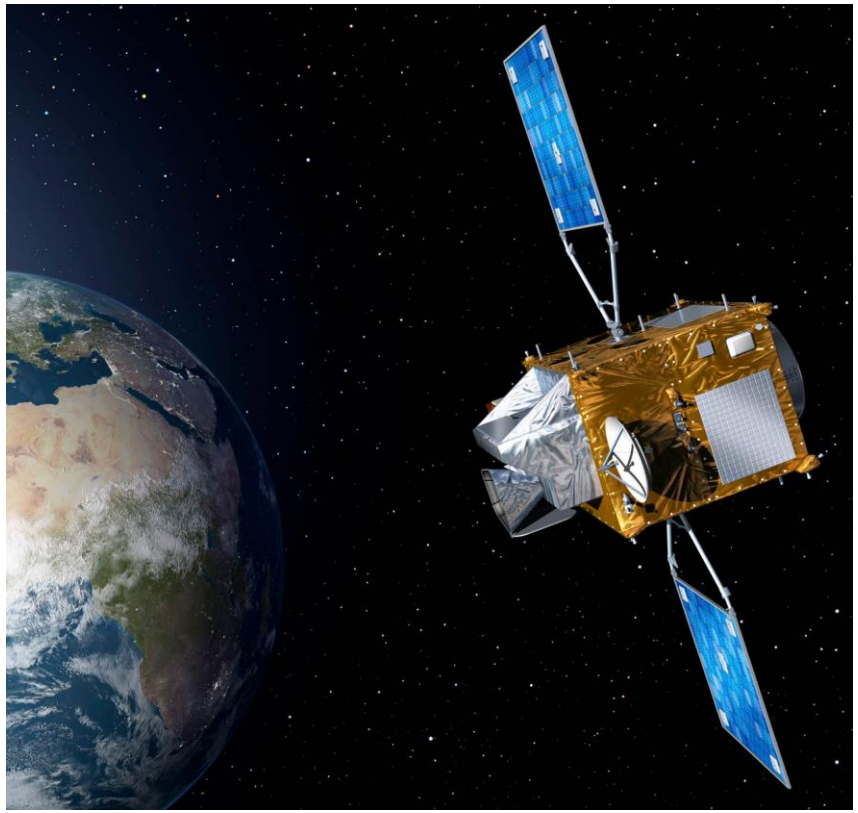
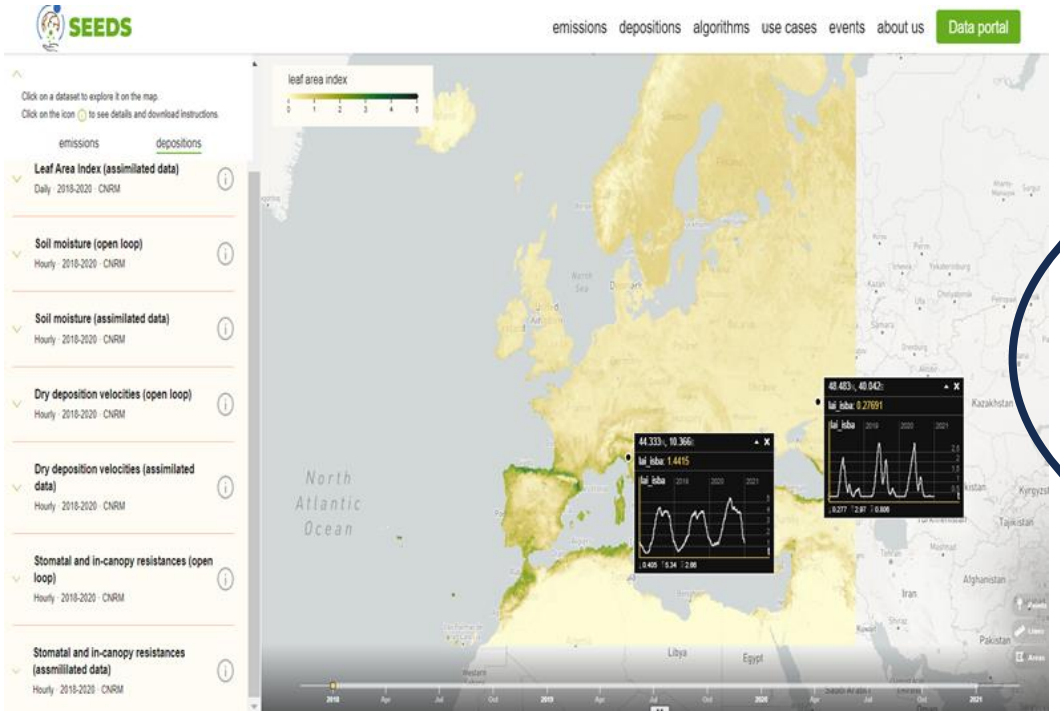


Sentinel 5P & Preparation for Sentinel 4

- The SEEDS project goal was 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 has developed techniques that may eventually become part of the Copernicus Atmosphere Service (CAMS).
- SEEDS has compiled a significant number of datasets in our portal for further evaluation.

SEEDS – 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 Daily top-down biomass burning emissions at 10 km resolution
- **Soil NOx** – 2019, 2020 -2022 Agricultural soil NOx emissions at up to 5 km resolution
- **BVOC** – 2018-2020 -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

SEEDS is part of CAMS evolution under the H2020 space program

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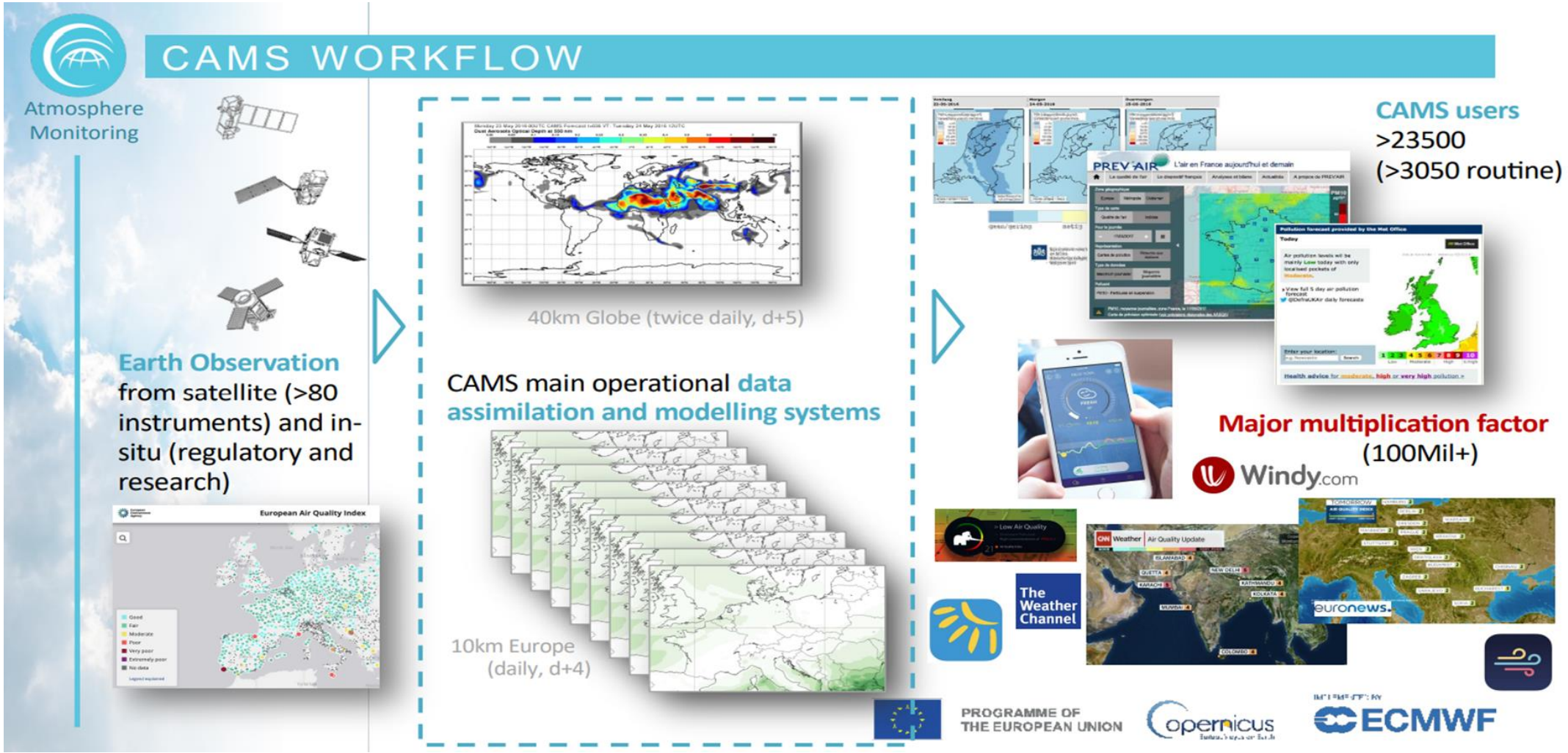
https://atmosphere.copernicus.eu **Global Daily AQ forecasts**



SEEDS – H2020 project

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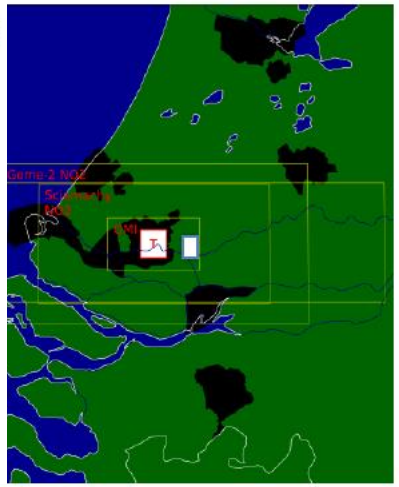
What makes TROPOMI unique?

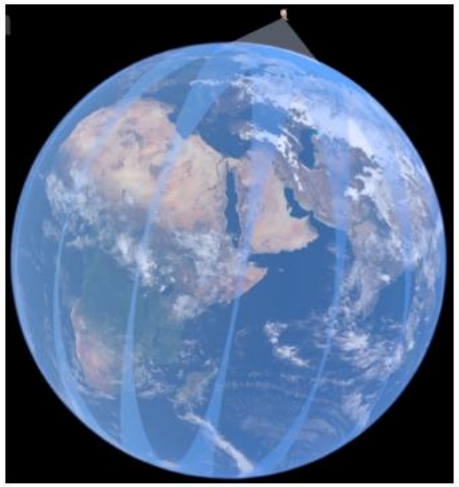
TROPOMI combines 4 unique features:

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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Up-to-date (UTD) anthropogenic emission estimates of NOx, NH_3 and biomass burning

SEEDS to prove the capabilities of satellite based – emissions and enable the provision of improved temporal emission products complementing the existing emissions currently available in CAMS.

Emission estimation method:

Inversion technique using satellite observations and a chemical transport model:

DECSO (developed by KNMI)

MAGRITTE v1 (developed by BIRA_IASB)

Products:

NO2 From TROPOMI

NH3 emissions from CRIS

HCHO from TROPOMI

Up-to-date (UTD) biogenic emission estimates for NOx and BVOC

SEEDS to produce new up-to-date emissions of biogenic organic compounds (BVOC) and soil emissions of nitrogen oxides (NOx) making use of satellite data through inverse modelling approaches and through data assimilation in land-surface vegetation models.

Emission estimation method:

Inversion technique using DECSO and MAGRITTE

MEGAN v3 based on SURFEX LAI and SM

Products:

NO2 from TROPOMI

HCHO from TROPOMI

LAI from Proba -V and AVHRR

Soil Nox emissions from satellites – added value

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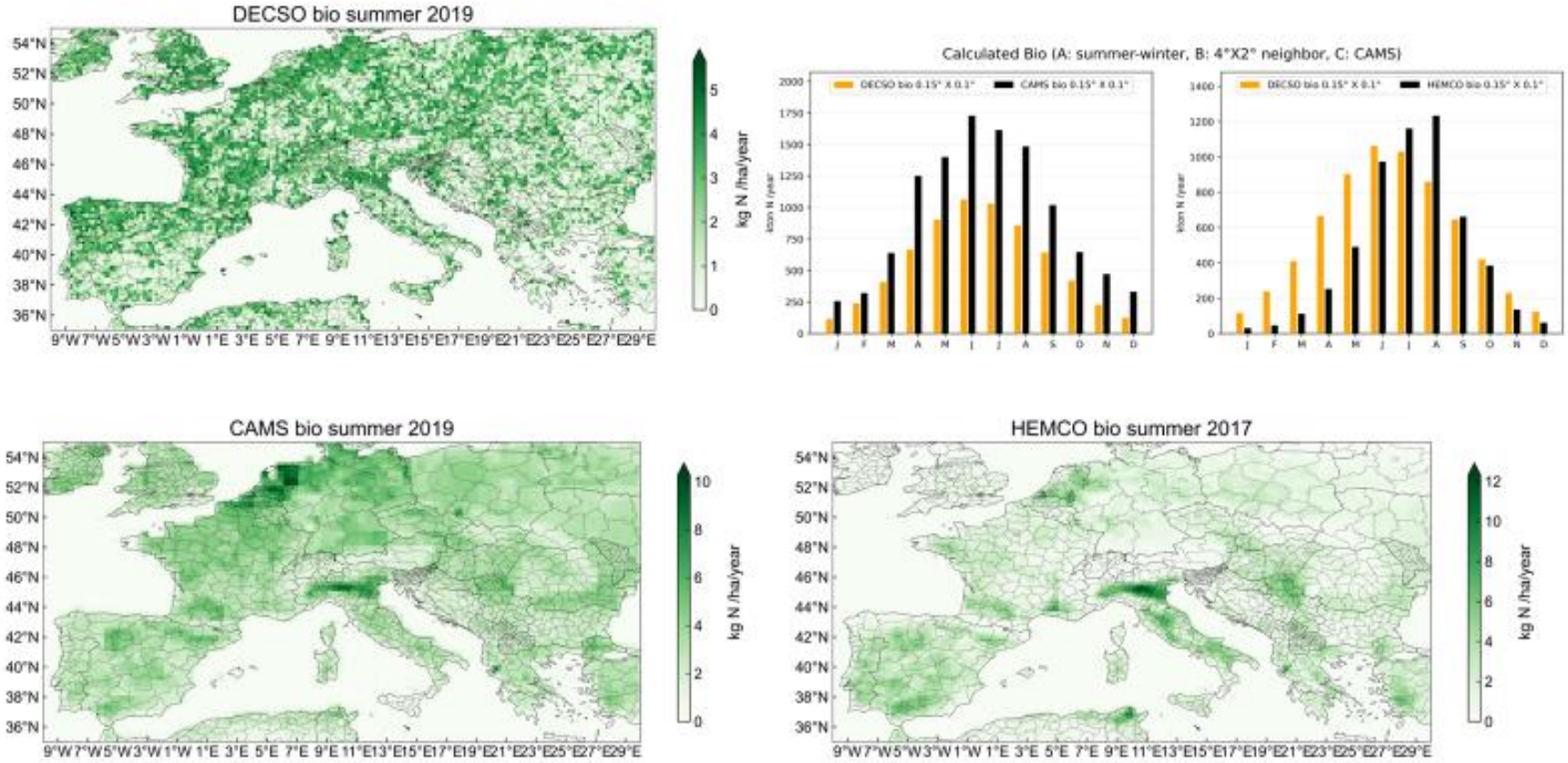
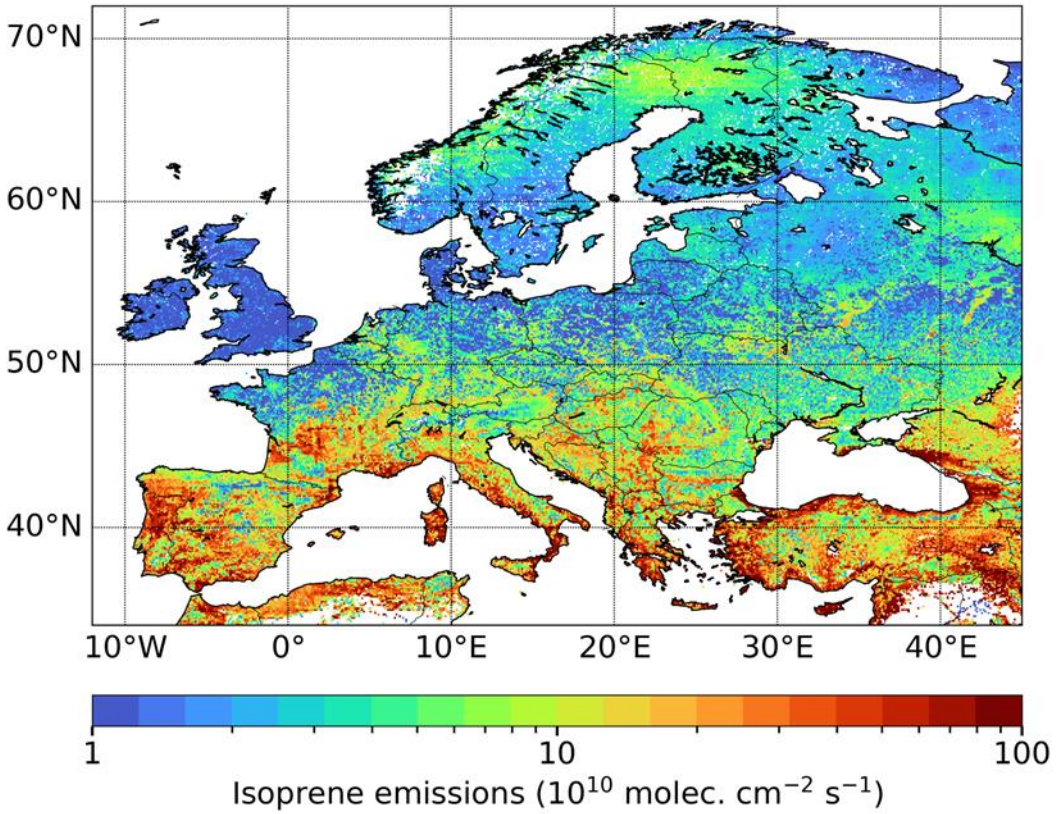
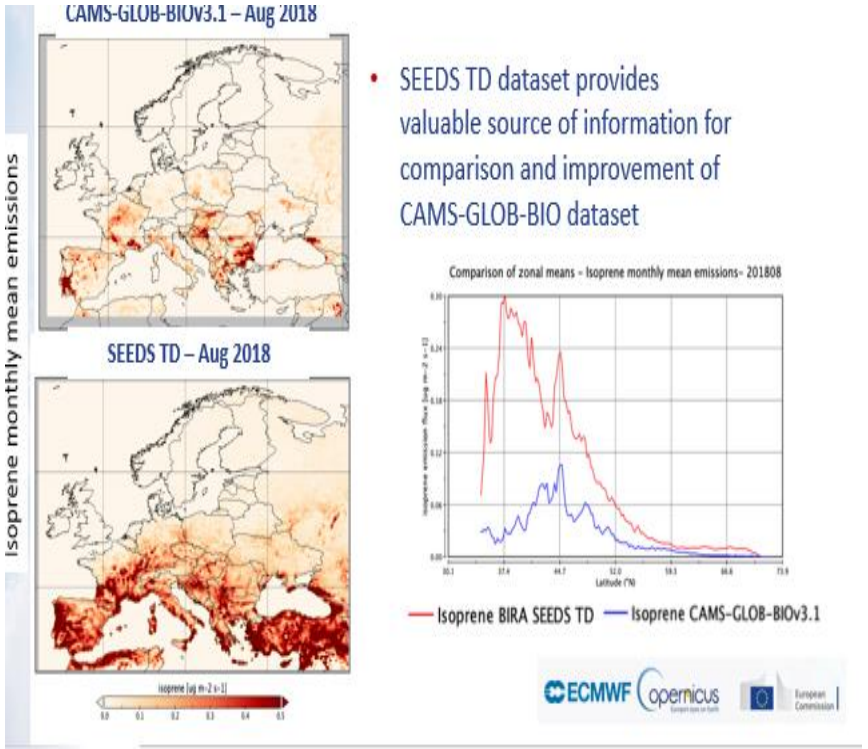
Results for Europe



Nox Soil from residual information using DECSO inverse modelling and TROPOMI satellite data

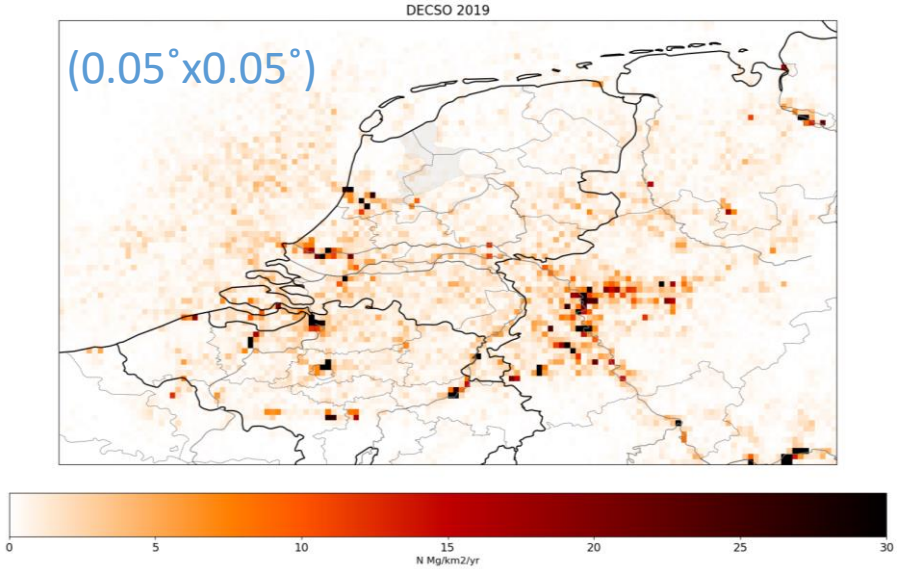
Biogenic VOC emissions from satellites

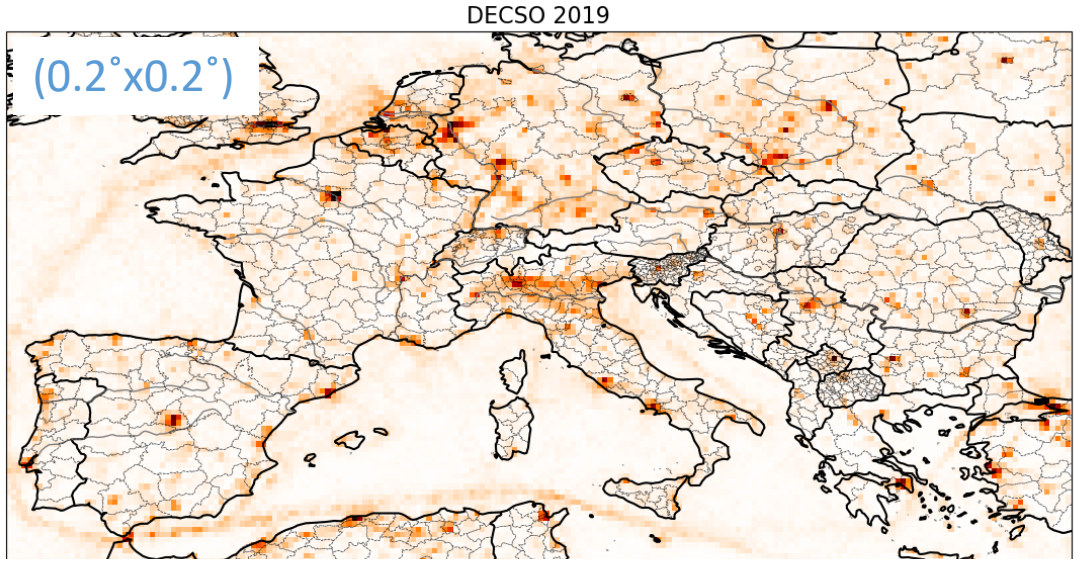


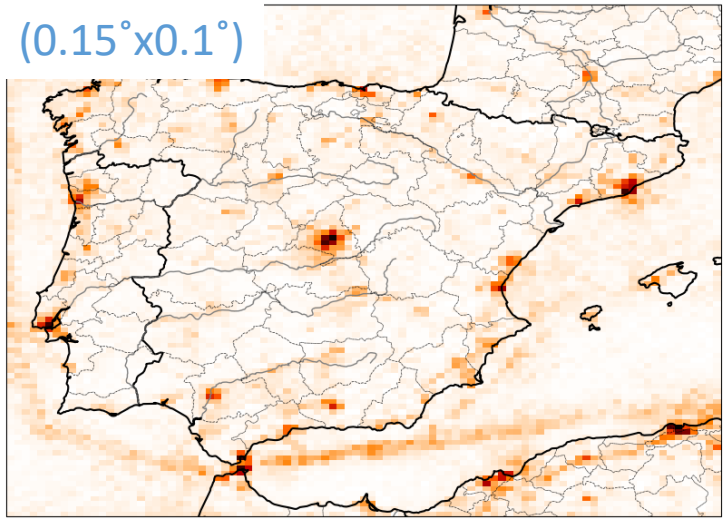


Large top-down BVOC emissions in **southern Europe** due to high (bias-corrected) HCHO column measurements from TROPOMI

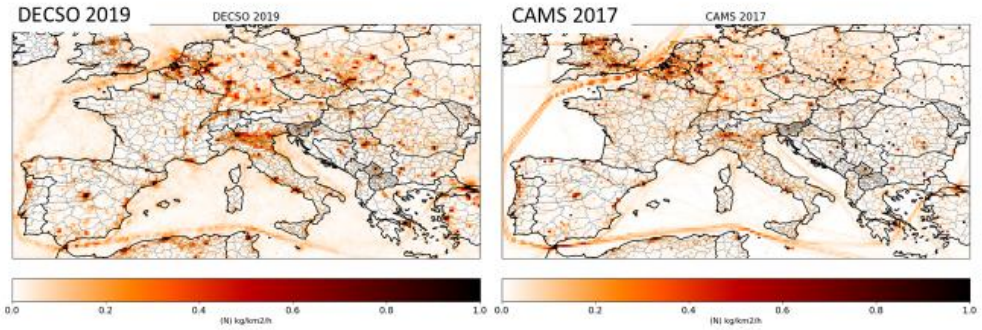
NOx emissions - Regions at various resolutions



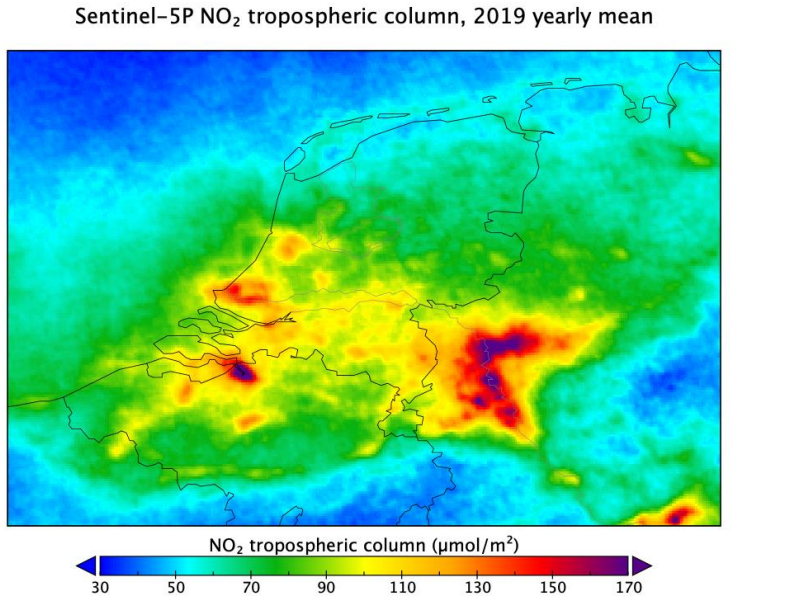


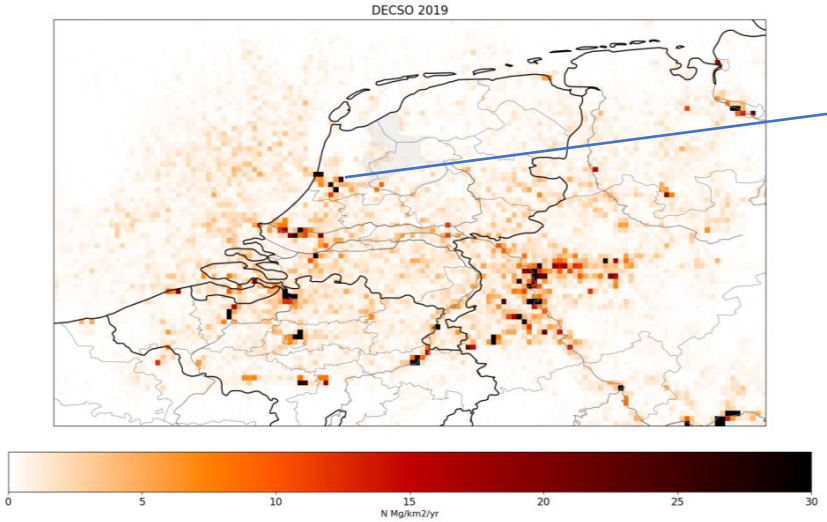


Comparison to CAMS emissions



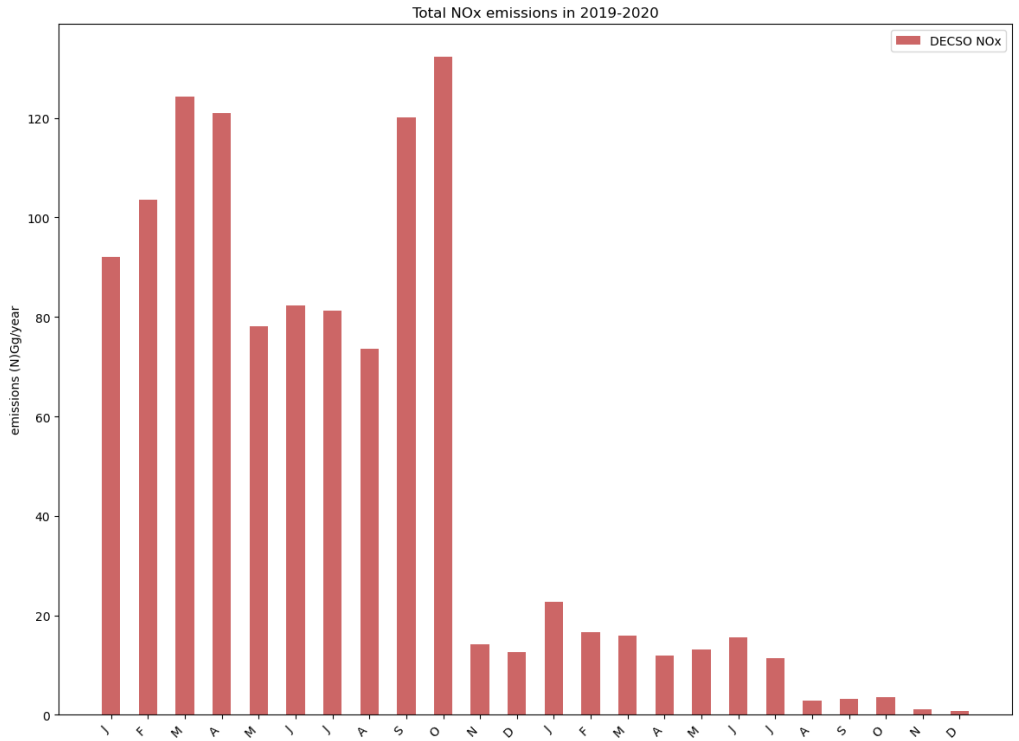
Timeseries checks with use of satellite data



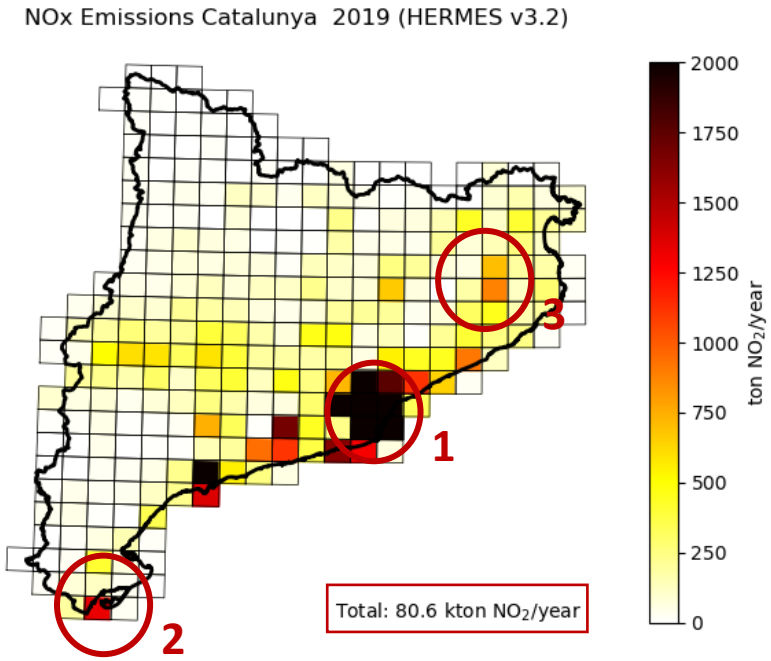


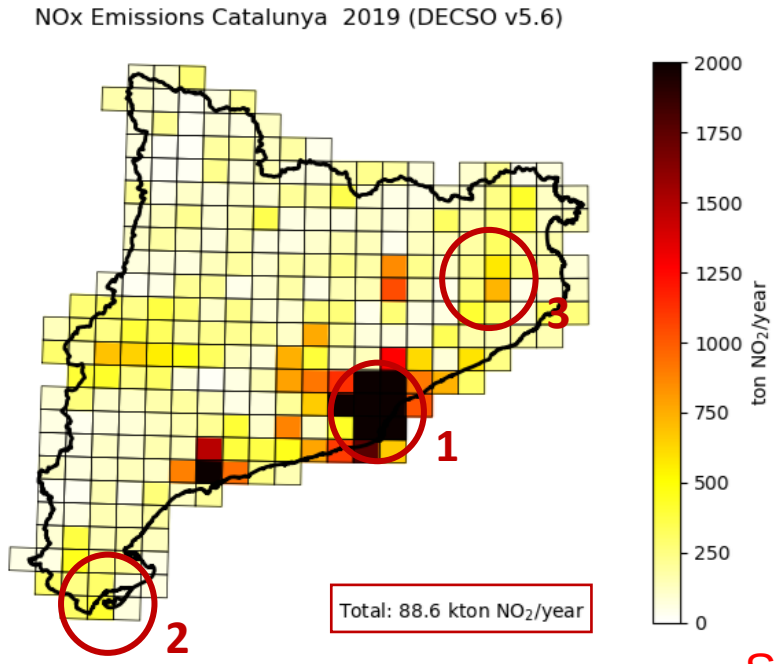
Going to a higher grid resolution: 3x5 km in the Netherlands

Powerplant “Hemweg centrale” decommissioned end of 2019

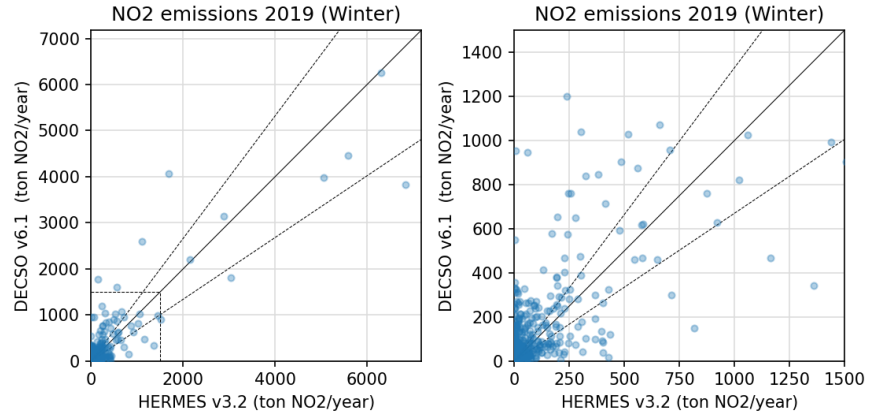


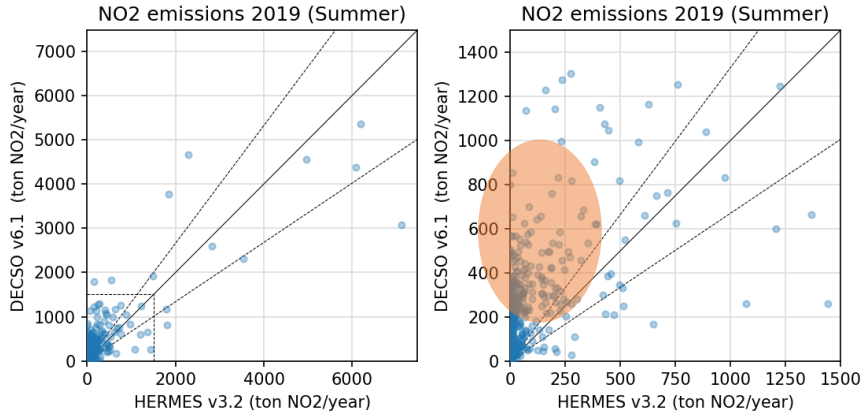
HERMESv3 versus DECSO





Soil NOx emissions

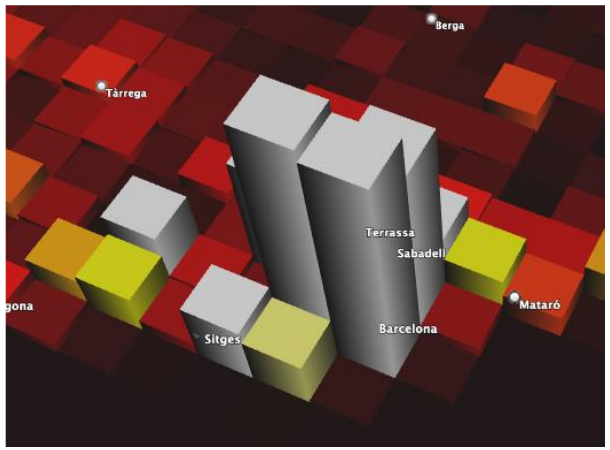
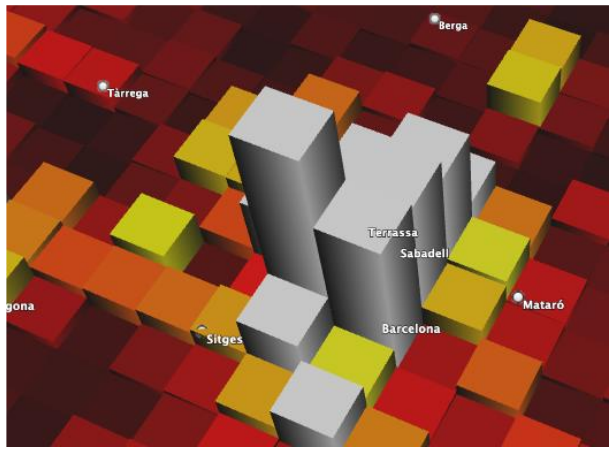


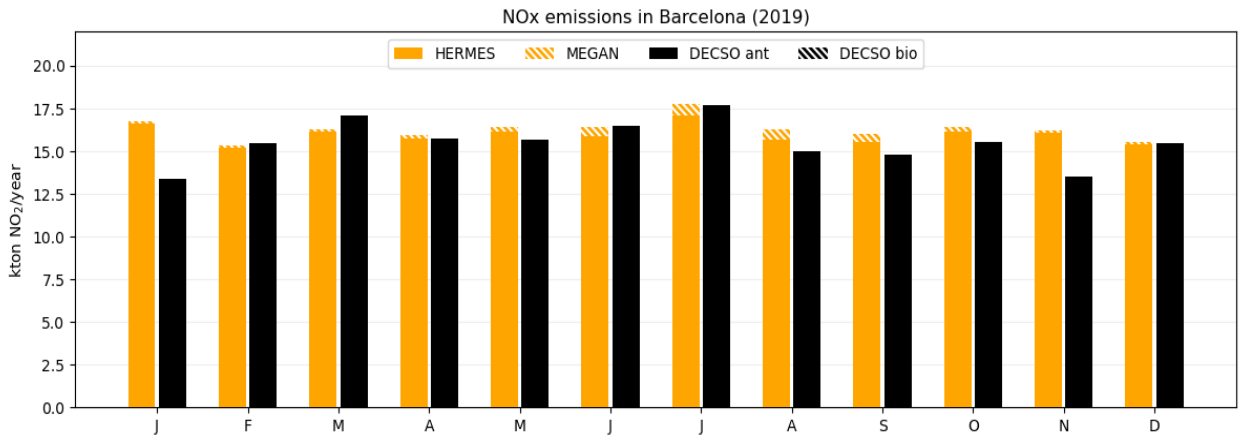


Barcelon Supercor Center Centro Nacio

Courtesy: Marc Guevara, BSC

Comparisons for NOx emissions in Barcelona area

HERMES v3.2	DECSO v6.1
	



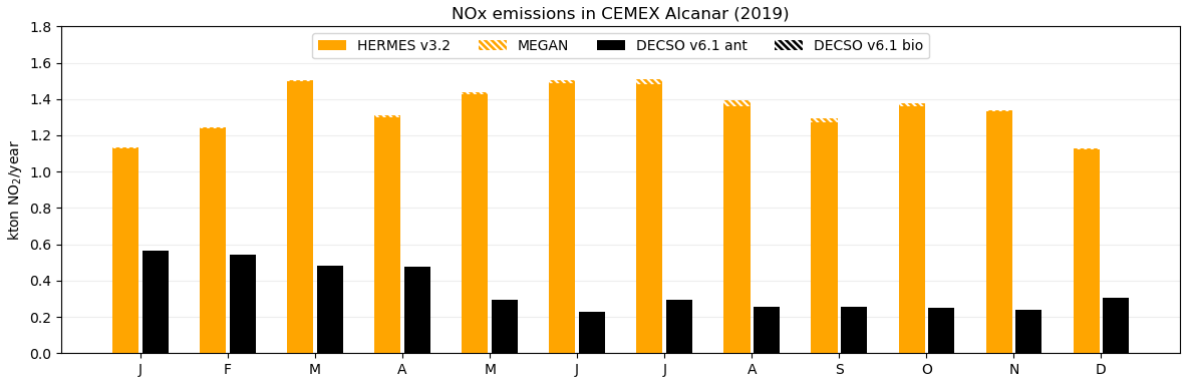
- 27.3 kton NO_2/year according to HERMES, which is about 34% of the total emissions found in Catalunya.
- DECSO estimates slightly less NOx emissions for this area: 26.1 kton NO_2/year.
- Although differently distributed over the grid cells, the aggregated emissions are well in line.
- No strong seasonalities identified neither in HERMES nor DECSO

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Courtesy: Marc Guevara, BSC

Industrial hotspot in Alcanar, Spain

HERMES v3.2	DECSO v6.1
	



- A strong registered point source in HERMES (**1.33 kton NO_2/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 NO_2/year**
- Results from the Continuos Emission Monitoring System provided by the Government of Catalonia indicate emissions of **1.1kton NO_2/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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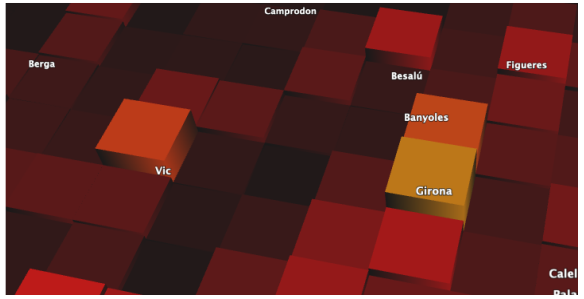
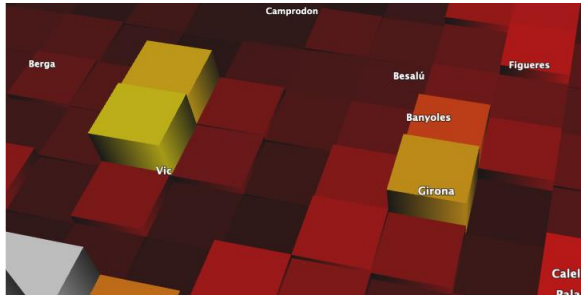
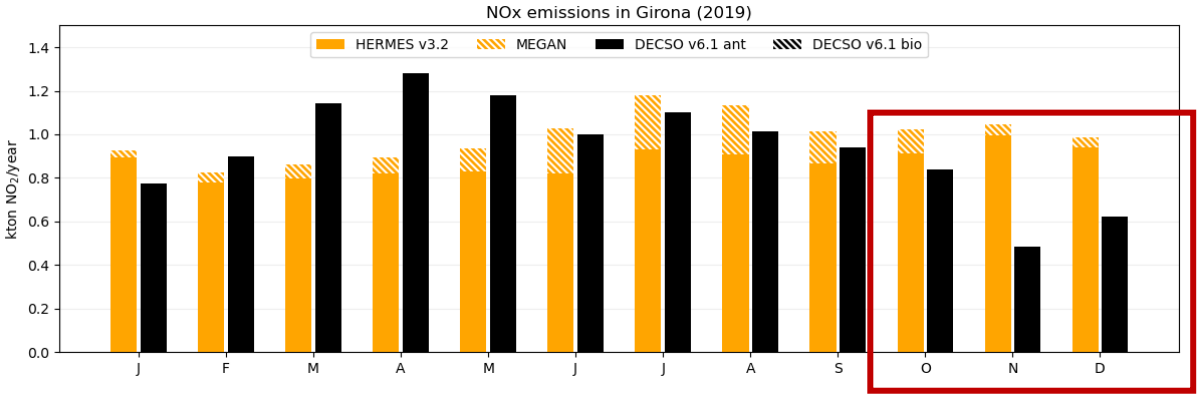
Centro Nacional de Supercomputación

Courtesy: Marc Guevara, BSC

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 re-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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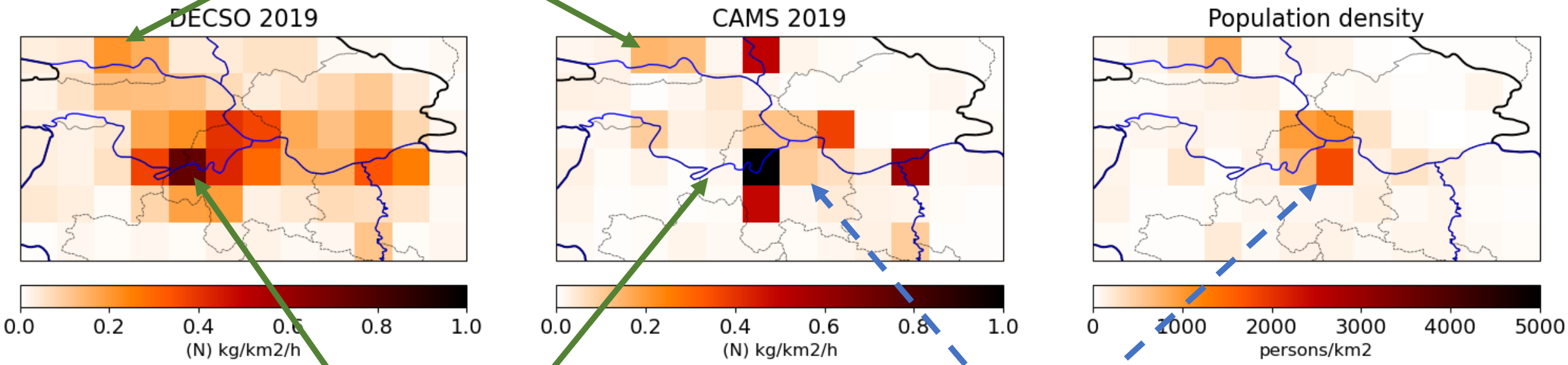
Courtesy: Marc Guevara, BSC

Biggest industrial emitters (NOx) in Serbia

Cement factory (Lafarge)

Note: this is the one of the biggest differences between CAMS and DECSO and clearly an exception.



3 power plants (Nikola Tesla)

Belgrade

Benchmarking ammonia emissions from satellites

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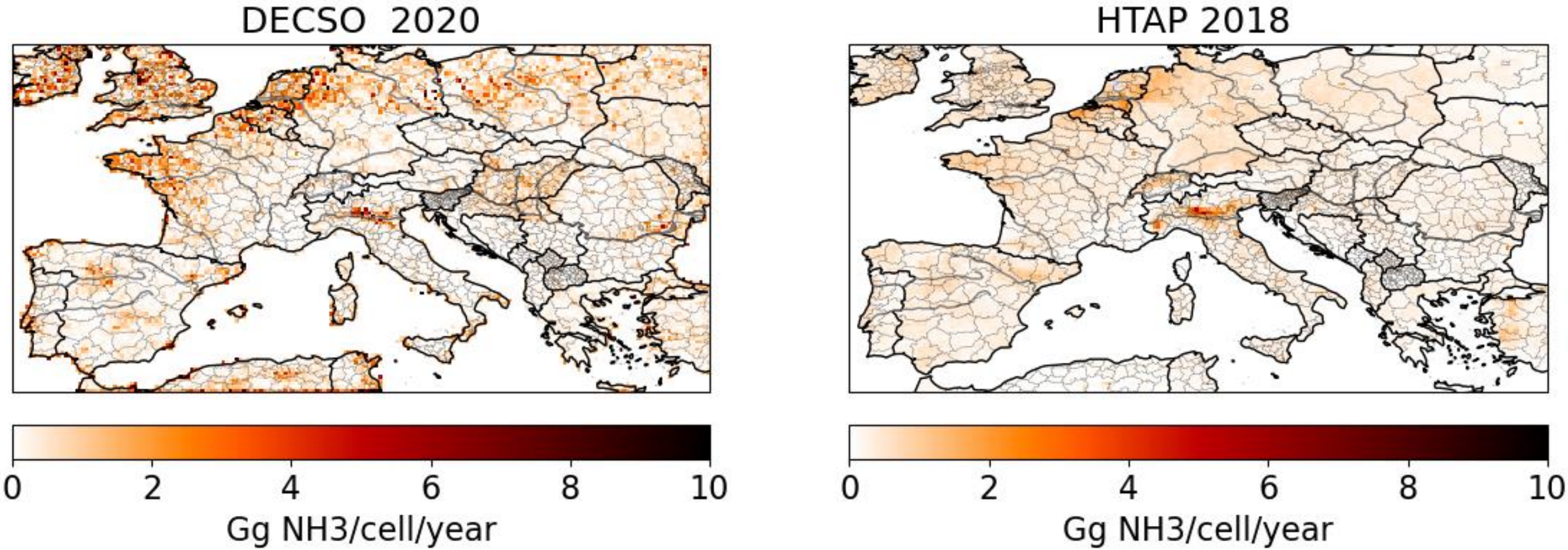
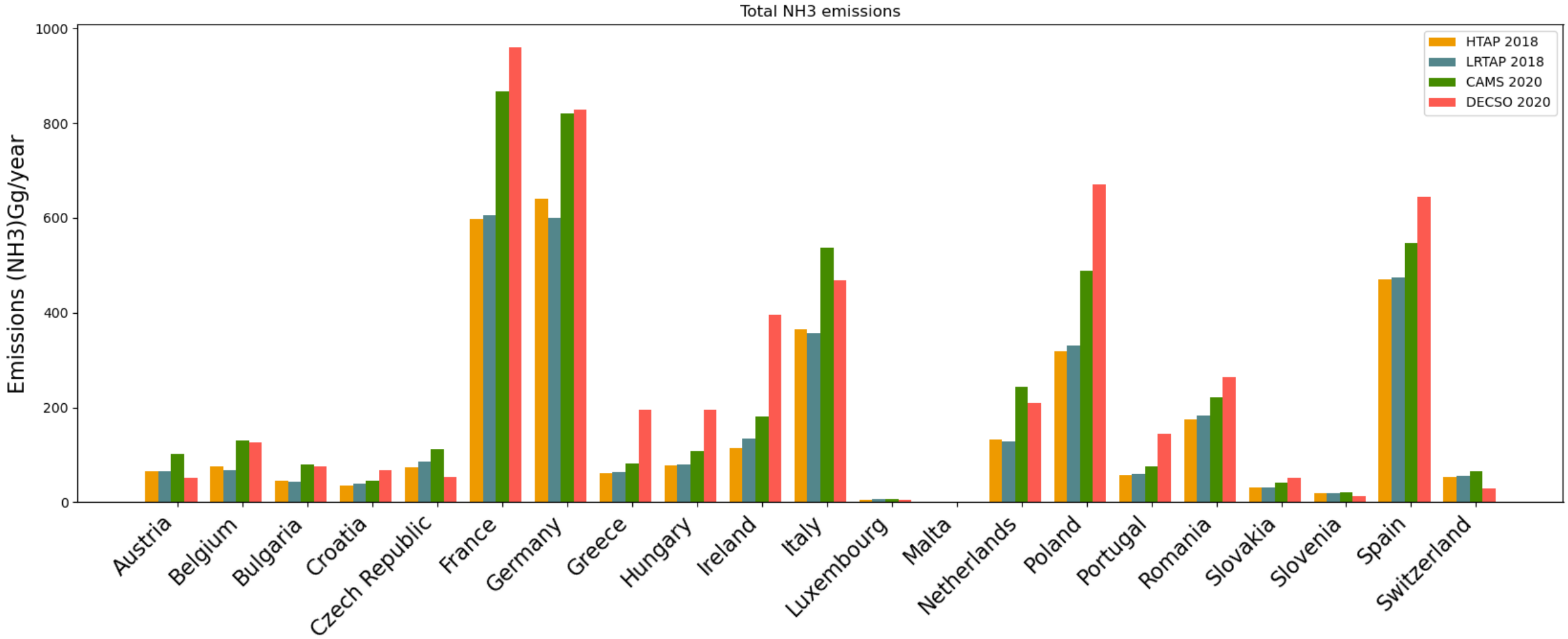
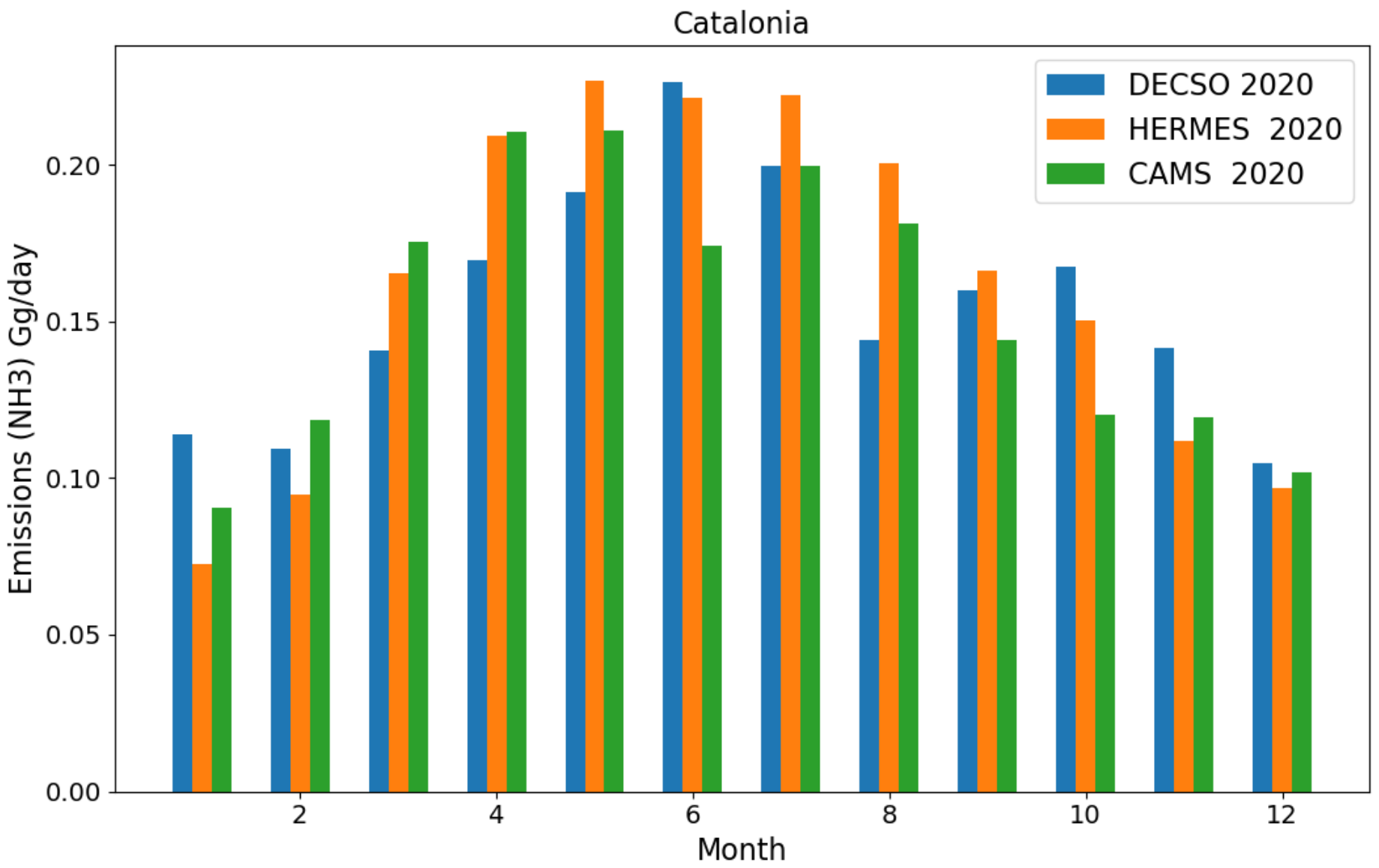


NH3: Spatial distribution of ammonia emissions

Ammonia Comparison of country totals top-down vs bottom-up emission estimate

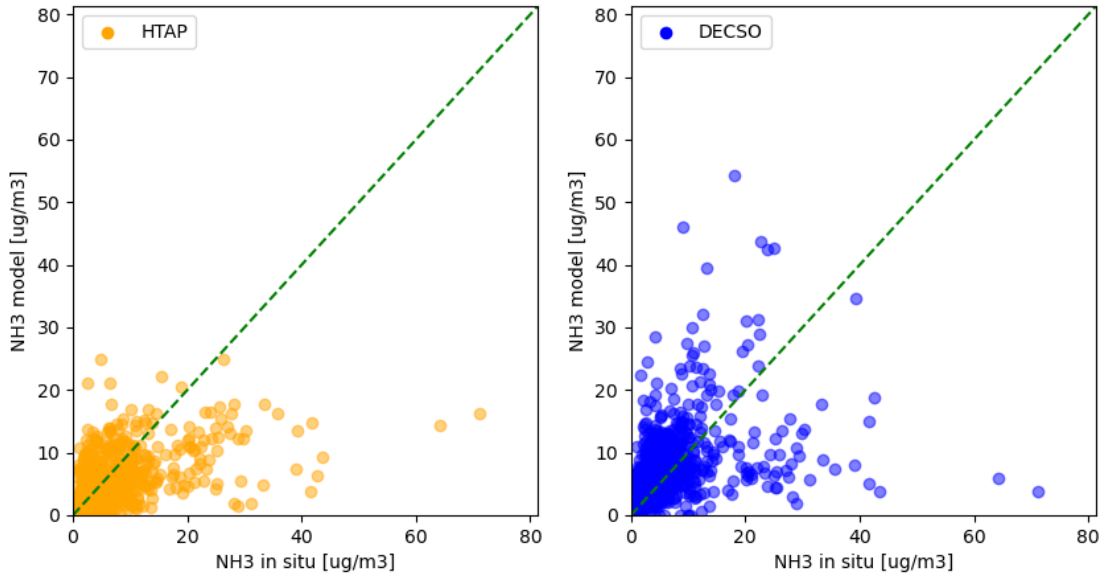


Monthly variations – Benchmarking in Catalonia

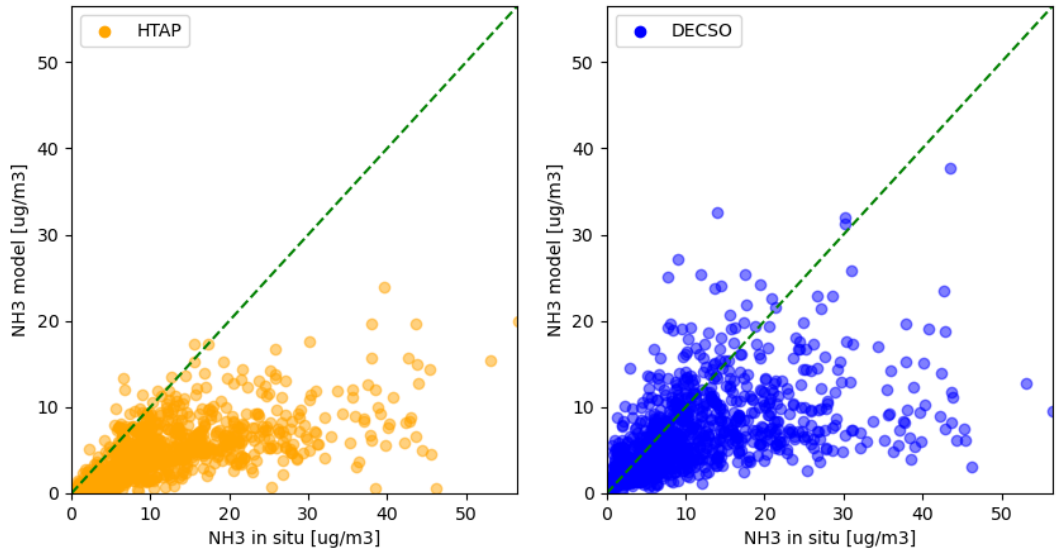


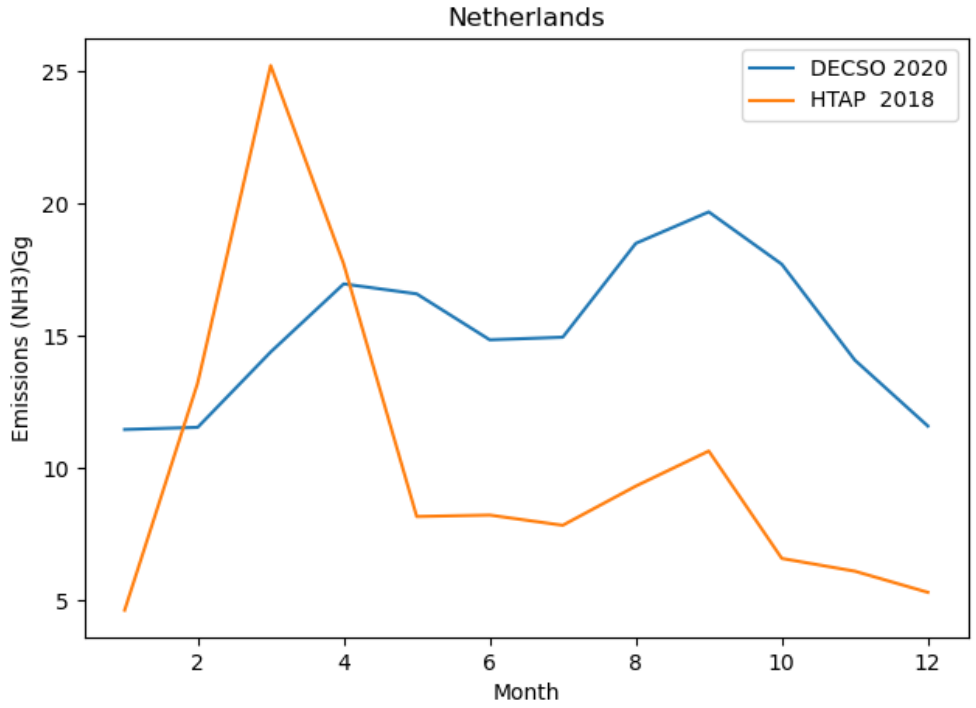
NH3 Benchmarking in the Netherlands

Winter months



Summer months





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Key messages

- Satellite AQ information through inverse modelling can be used to support the review and verification of emission data - cooperation between TD+BU communities = enhanced knowledge

  - **Location/Resolution**
    - Spatial resolution of EO-based emissions still a challenge – even with TROPOMI
    - Locating sites - of very limited value in most European countries - Possibly applications in other parts of the world
    - NOx soil emission in summer identify from satellite
  - **Timeseries and time variations**
    - Verifying year to year variations -
    - Estimating monthly/weekly variations in emissions – Sentinel 4 is Geostationary and will enable diurnal variations
    - Checking emissions from sources that drop below thresholds… and gap filling datasets
  - **Emission outlier checks**
    - Reported vs EO-based emissions – even if EO-based data is not specific to a point source, is still of value in identifying issues.
    - Possible additional analysis with pollutant ratio checks for instance with CO can be informative for QA/QC purposes

Thank you for your attention !