Koninklijk Nederlands
Meteorologisch Instituut
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Satellite-derived NOx emissions over Europe from TROPOMI

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- Deriving NOx emissions from TROPOMI observations
- Verification of the emission data
- Split-up in source sectors

SEEDS
Sentinel EO-based Emission and Deposition Service

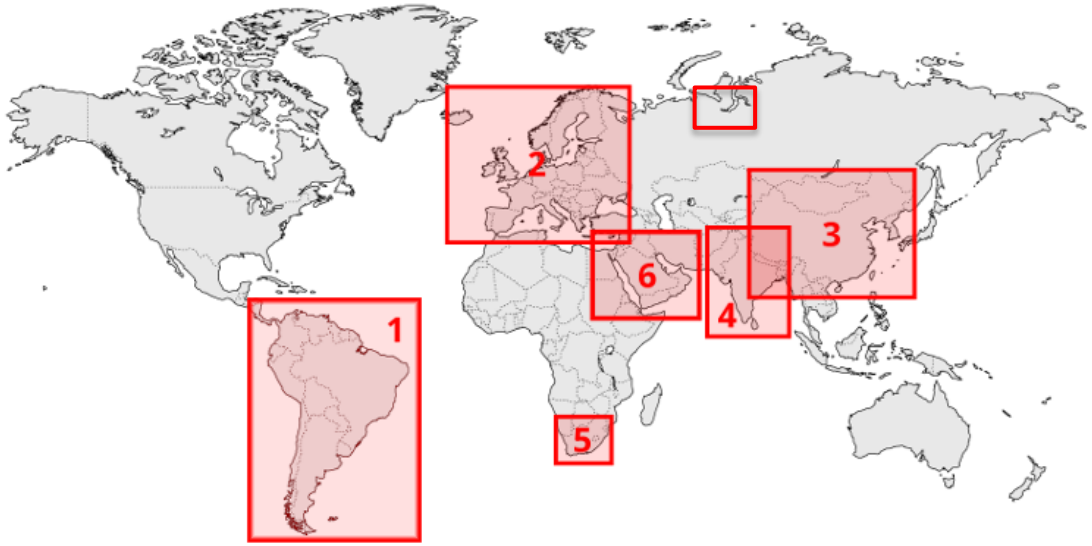
This work is part of the H2020 project SEEDS.

SEEDS develops pollutant emissions and depositions to support CAMS.

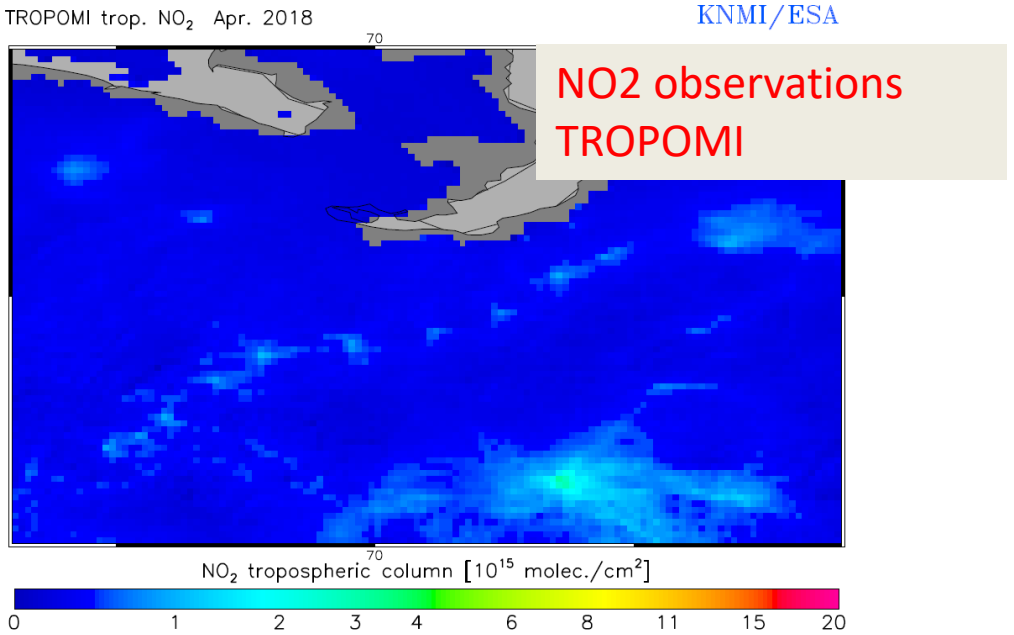
DECSO Daily Emissions Constrained by Satellite Observations

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 using a Kalman Filter, CHIMERE (CTM) and TROPOMI NO_2 observations
- It is fast: one model run per assimilation step of one day
- No *a priori* information needed.
- Full error estimation

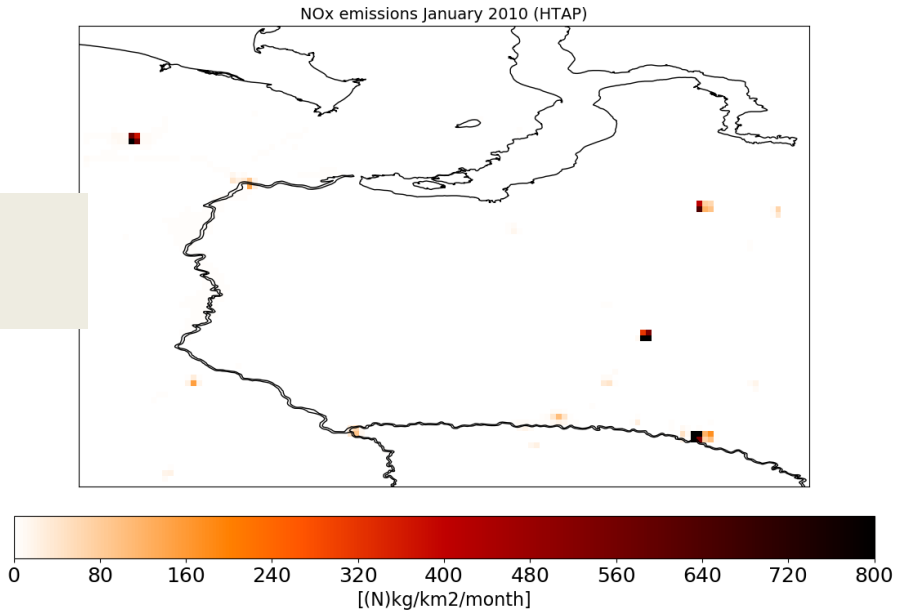


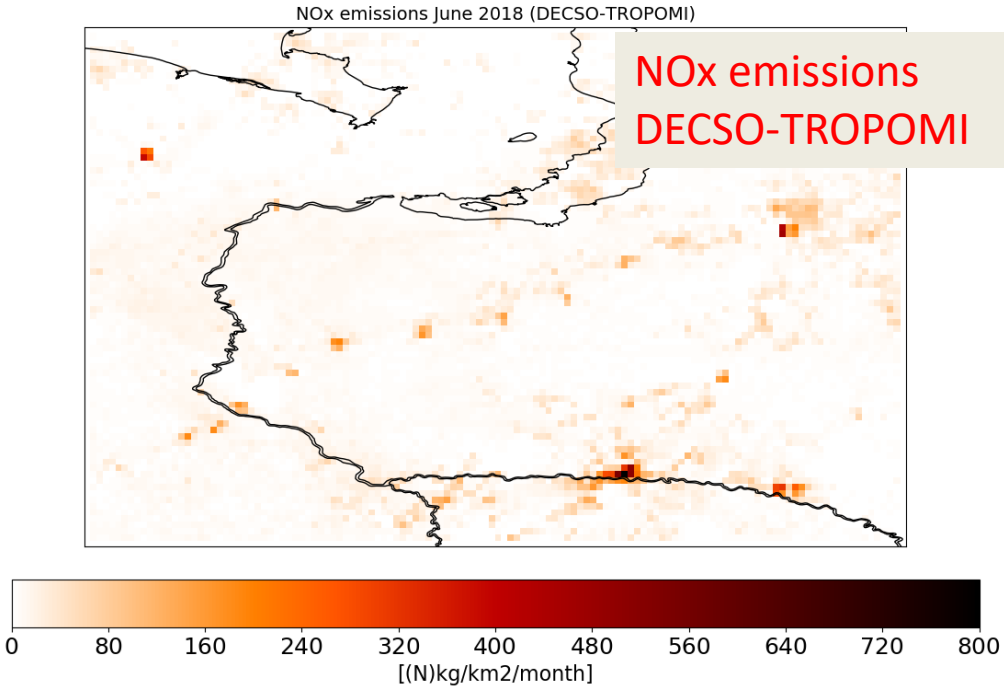
West Siberia: gas compressor stations along pipeline to transport gas to Europe show up in map of NOx emissions



Van der A et al., npj Clim. Atmos. Sci., 2020

NOx emissions HTAP





1. Development DECSO-NOx to version 5.6

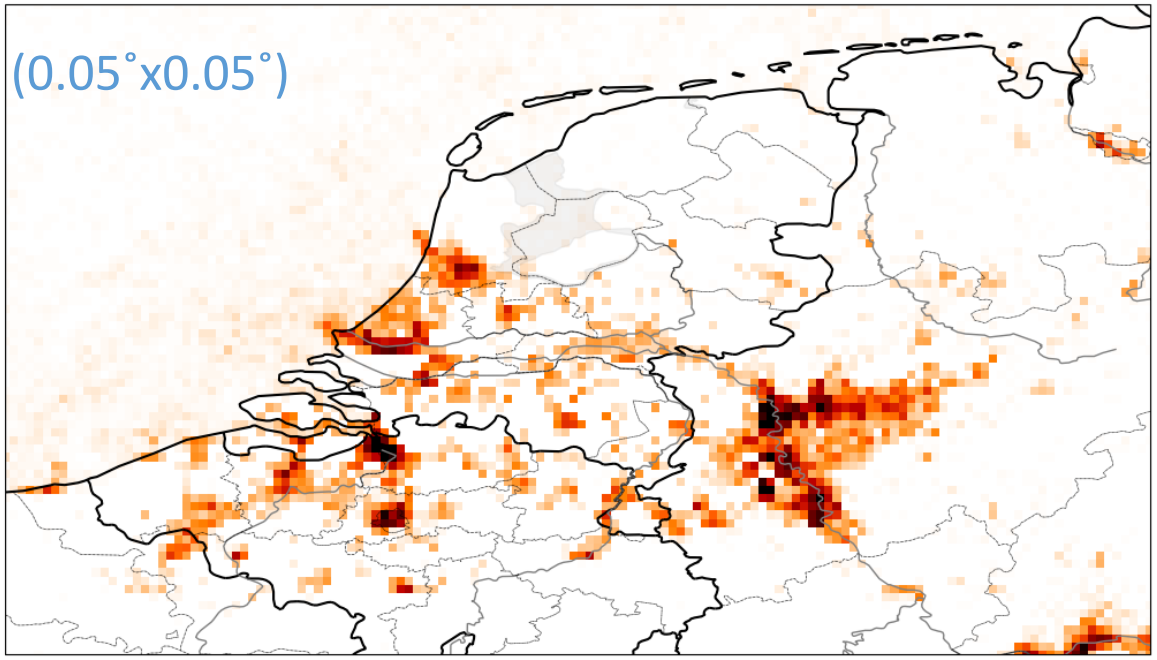
Important improvements:

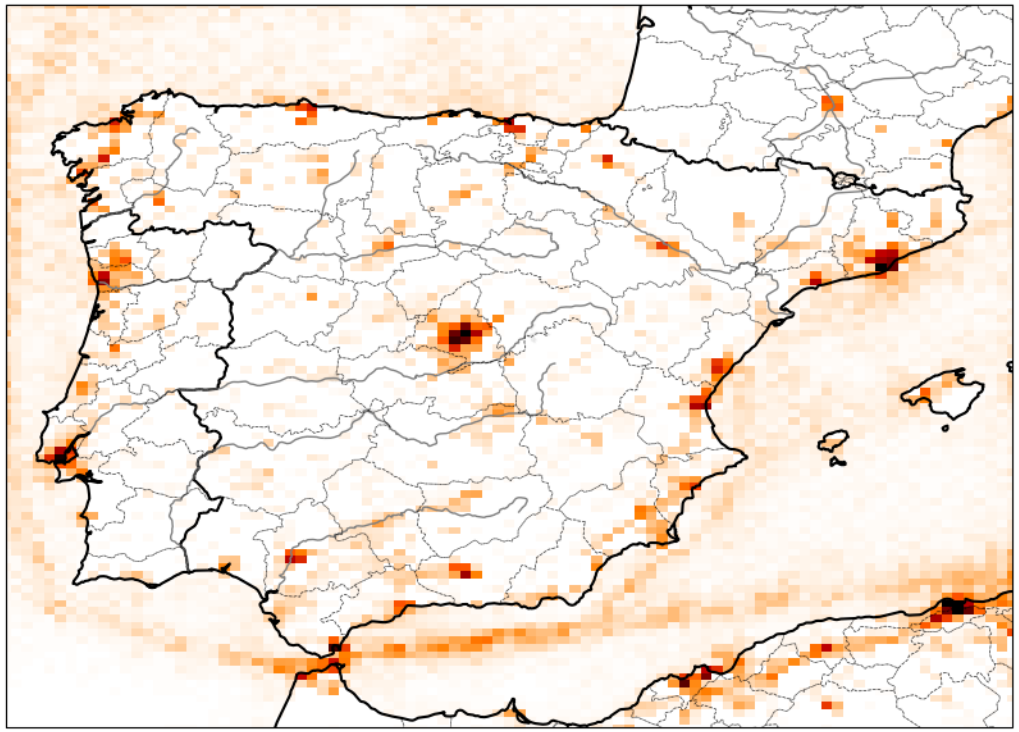
- New NO2 retrievals (PAL version v.2.3.1)
- The use of super-observations limited to 700 hPa (level 2 data).
- Update of CHIMERE (still in progress)

Other technical developments:

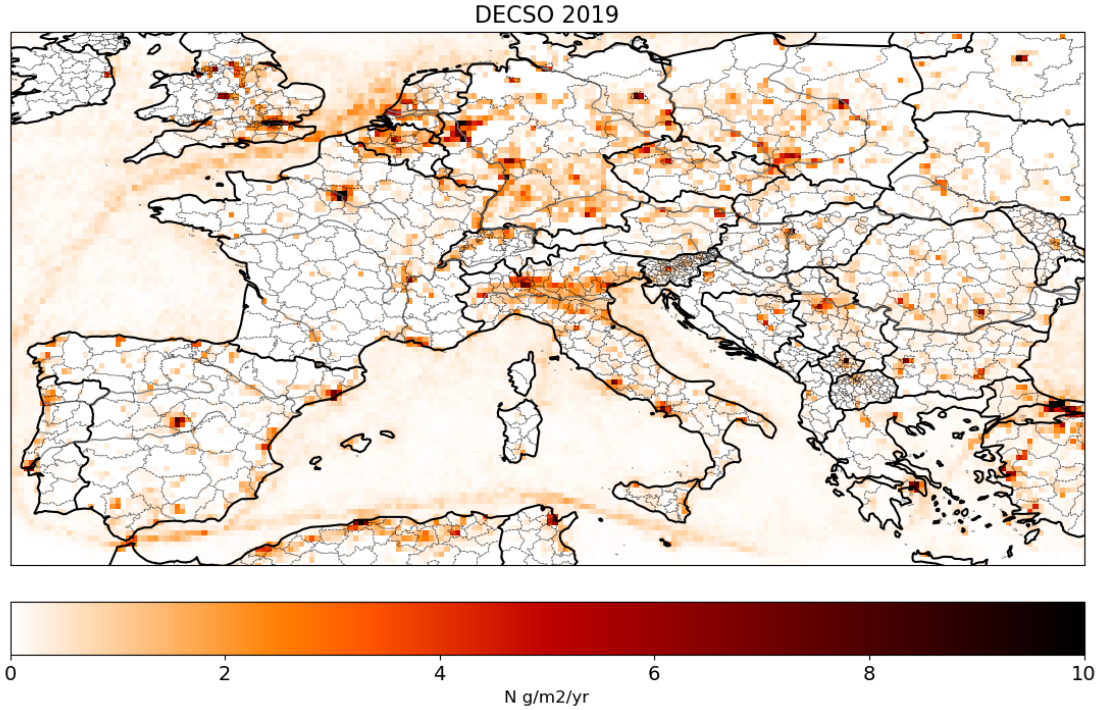
- New parametrizations are derived for the covariance matrices that describe the errors due to the model, measurements and representation.
- The correlation length of the errors in emission estimates was decreased.
- Update of the land-use to the Copernicus Landcover 2019 database.

European Regions

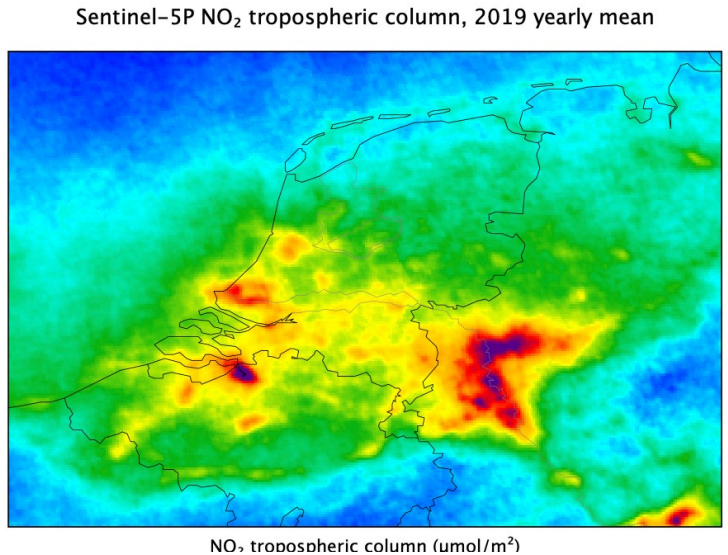




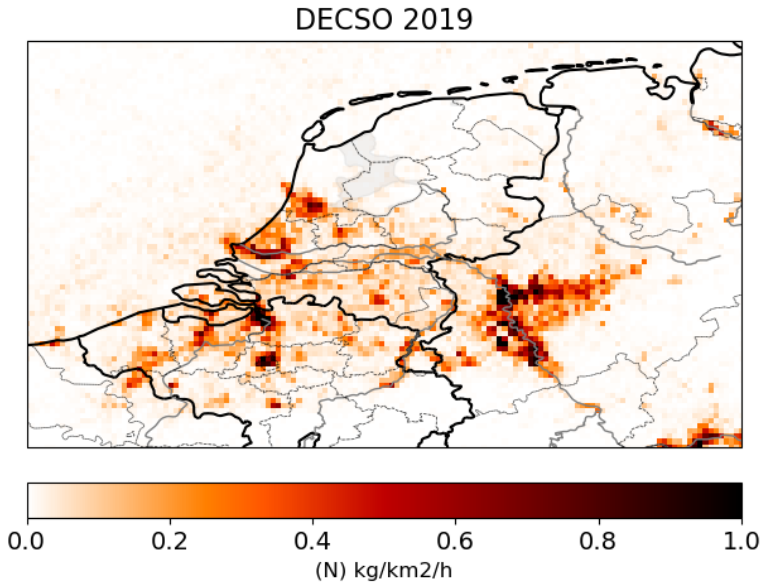
(0.15˚x0.1˚)



(0.2˚x0.2˚)



- Averaged TROPOMI NO2 observations (3.5x5 km)
- Meteorology plays a role



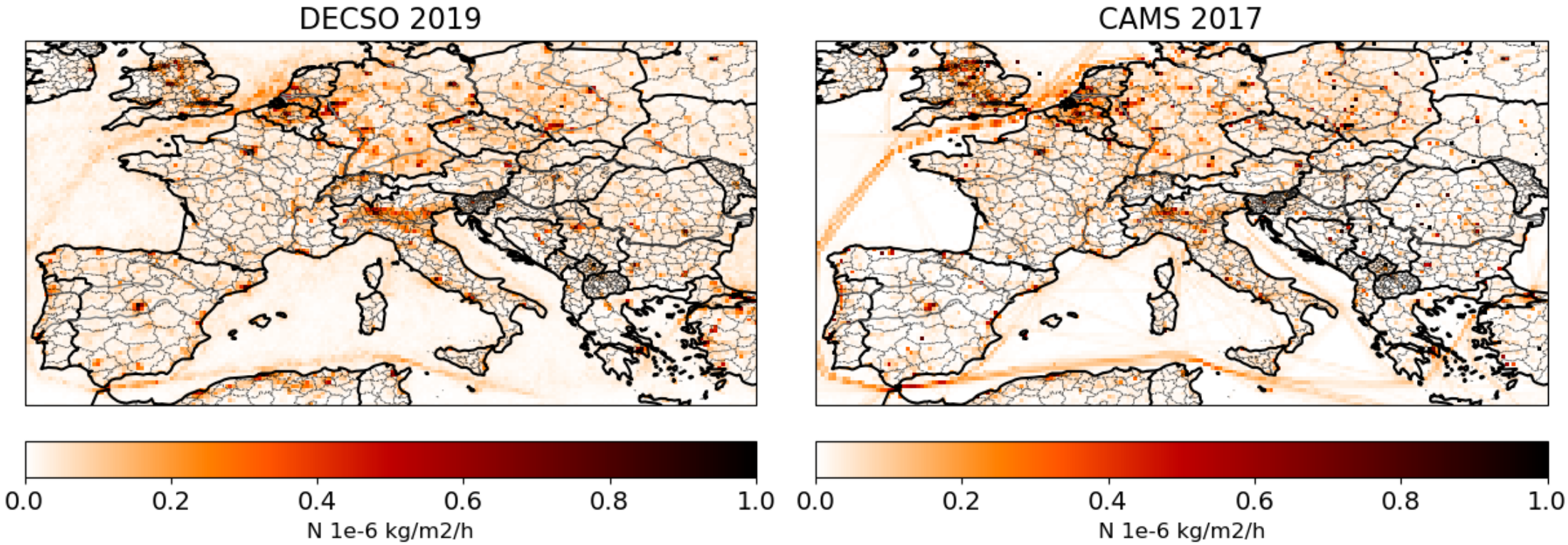
- Calculated NOx emissions (daily)
- Resolution is 0.05˚ (4-5 km)

2. Verification of our emissions

- Verification is difficult since there are hardly any direct surface flux measurements.
- The precision of emissions is often high, but the accuracy is unknown…

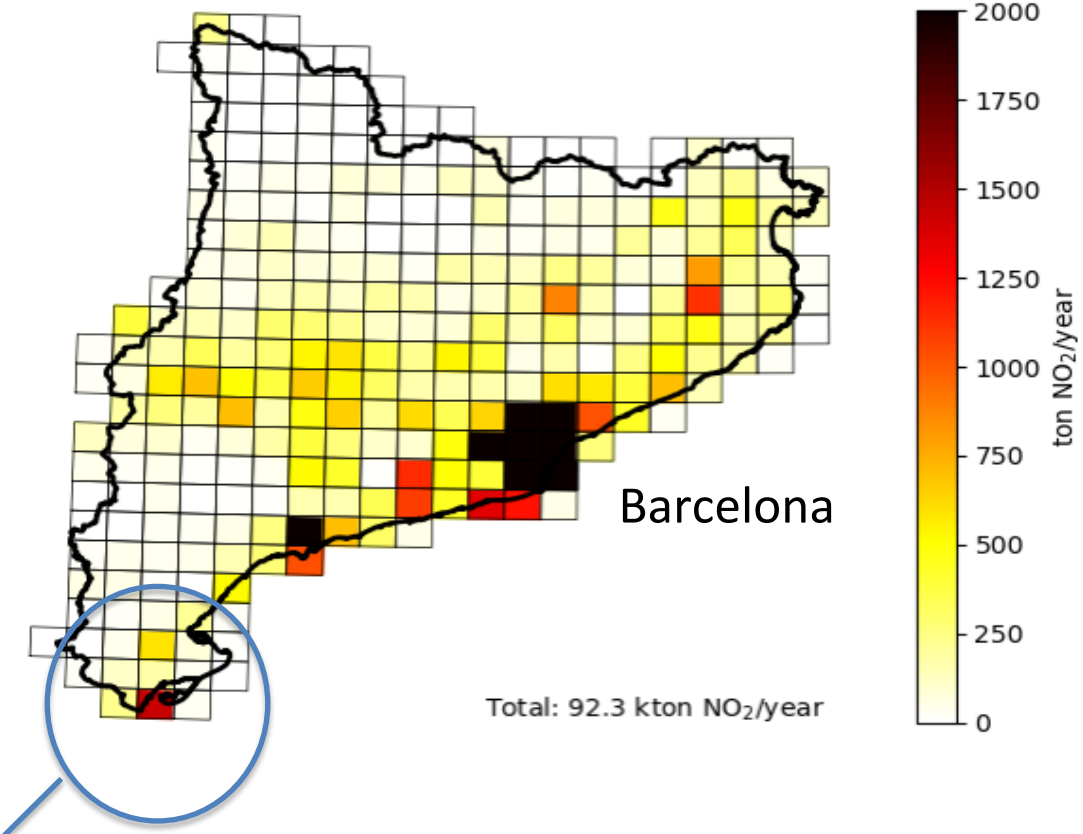
- Intercomparison to bottom-up emissions for verification is beneficial for both methods.

European NOx emissions



Comparison with regional bottom-up inventory HERMES (Catalonia, Spain)

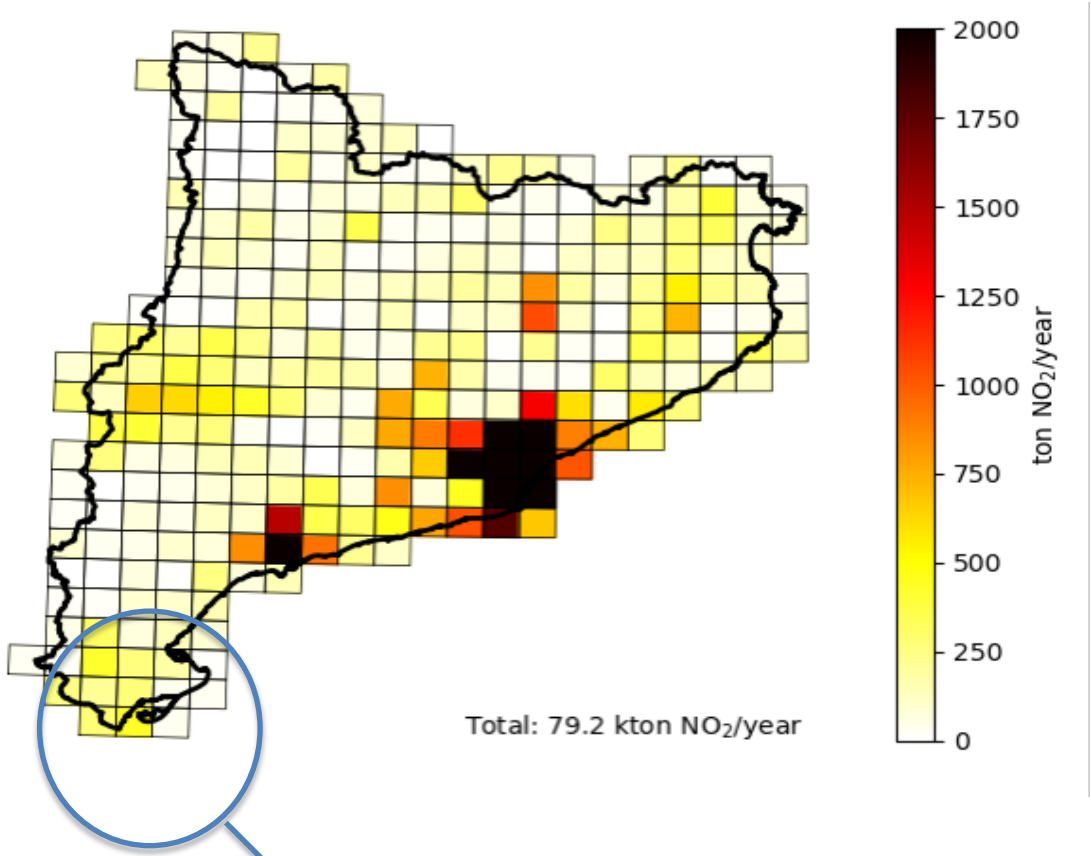
HERMES



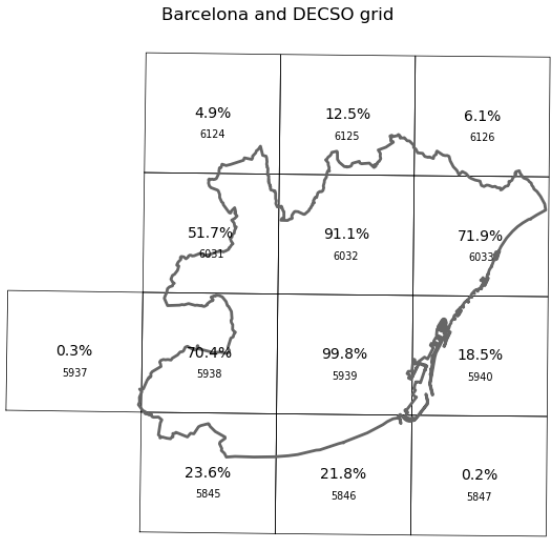
HERMES predicts a major point source:
Alcanar Cement production plant

Credits: Barcelona Supercomputing Centre

DECSO



But TROPOMI observes no, or only a small NO2 enhancement over the background



Timeseries NO_X emissions Barcelona

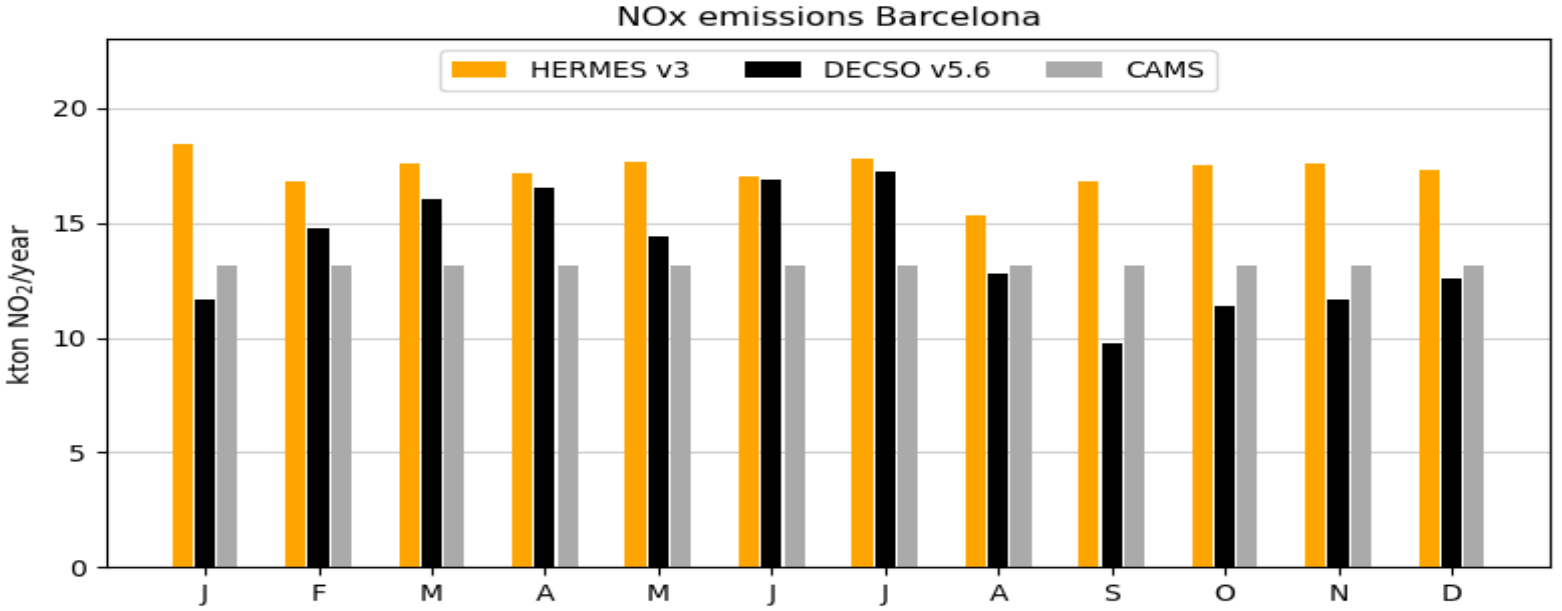
Total emissions

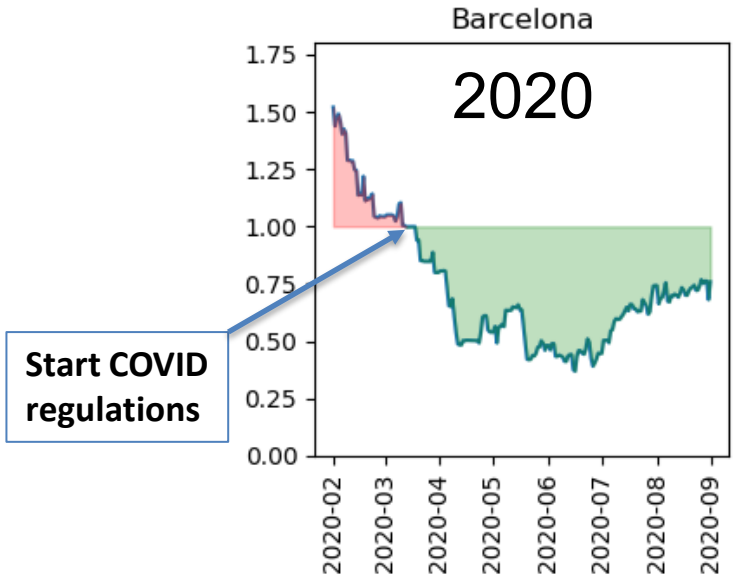
HERMES v3 (2019): 17.3 kton NO_2

DECSO v5.5.9 (2019): 13.8 kton NO_2

CAMS (2017): 13.2 kton NO_2

2019



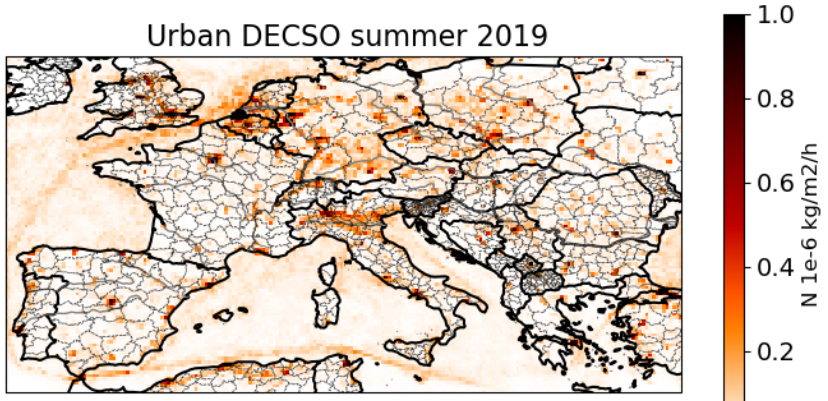


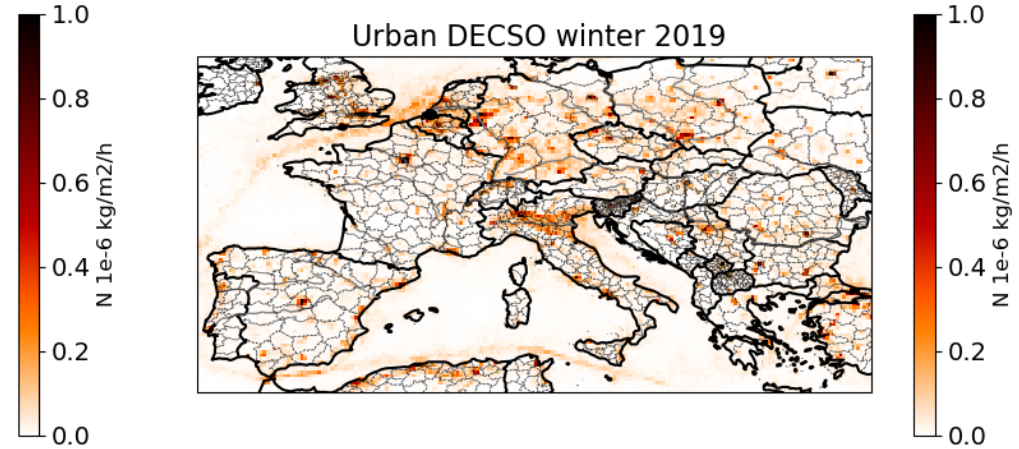
3. Split-up in anthropogenic and biogenic source sector

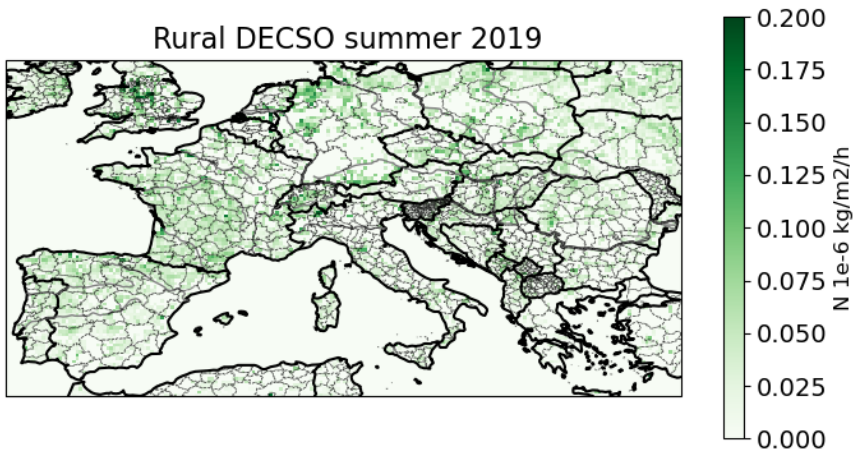
Distinguish sectors per grid cell based on the following assumptions:

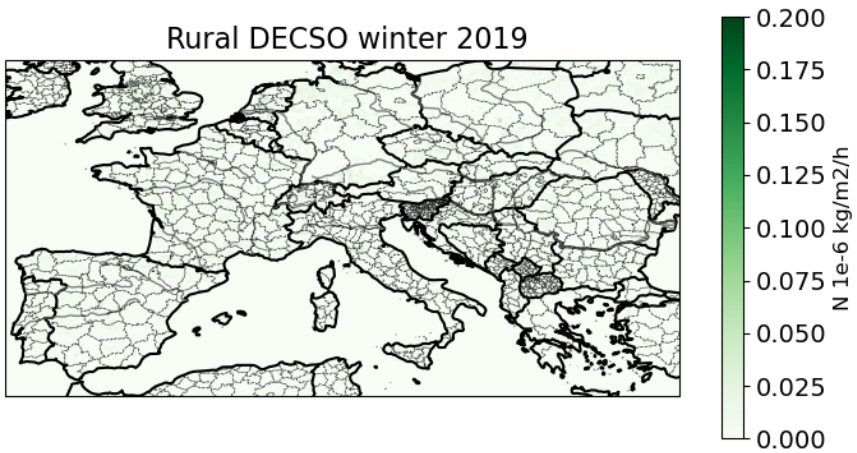
1. Biogenic emissions in winter can be neglected, but have a strong signal in summer
2. Anthropogenic emissions do not show a seasonal cycle
3. All emissions over sea are of anthropogenic origin

Anthropogenic and biogenic NOx emissions of Europe

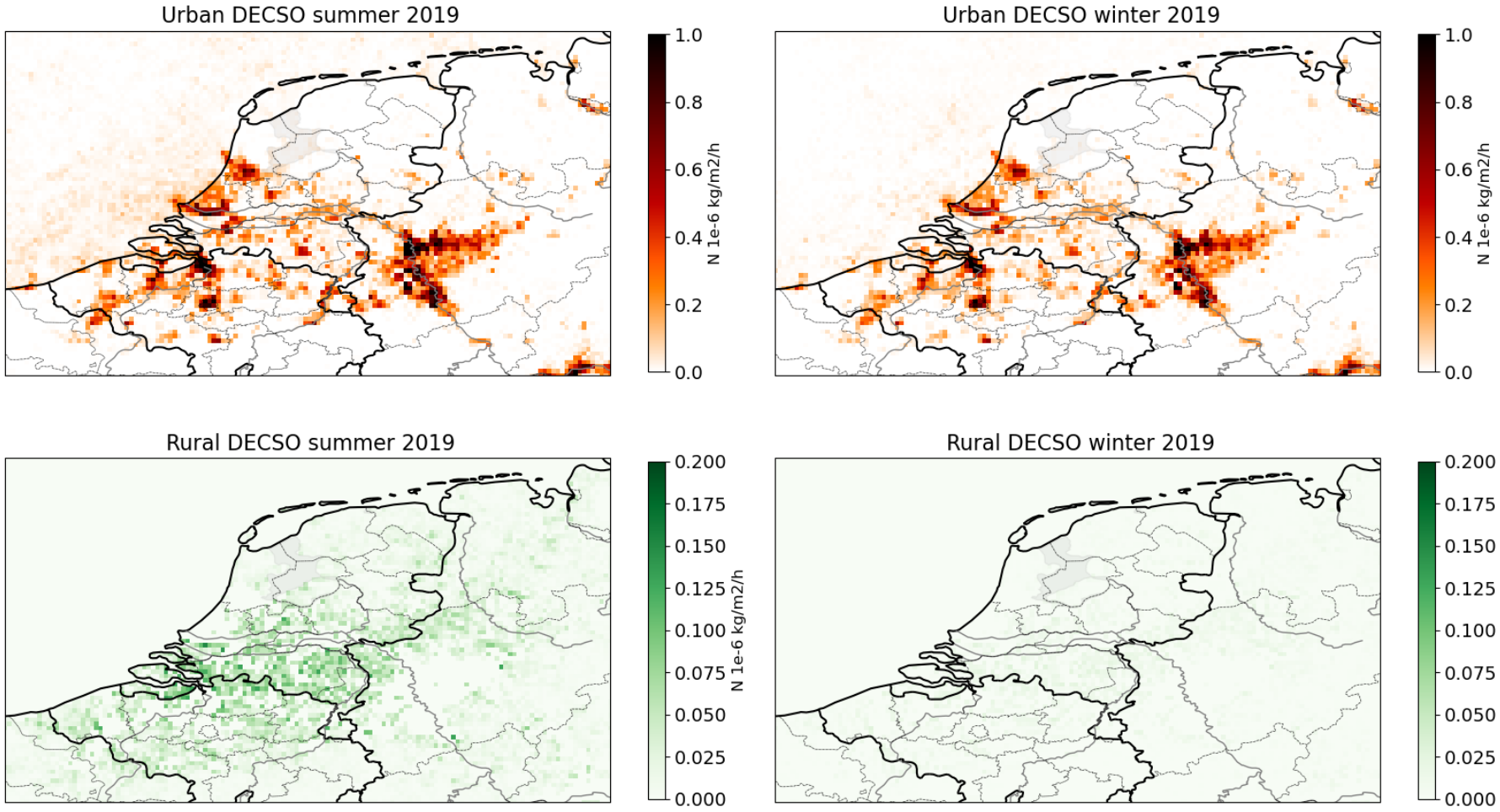








Anthropogenic and biogenic NOx emissions of the Low Countries

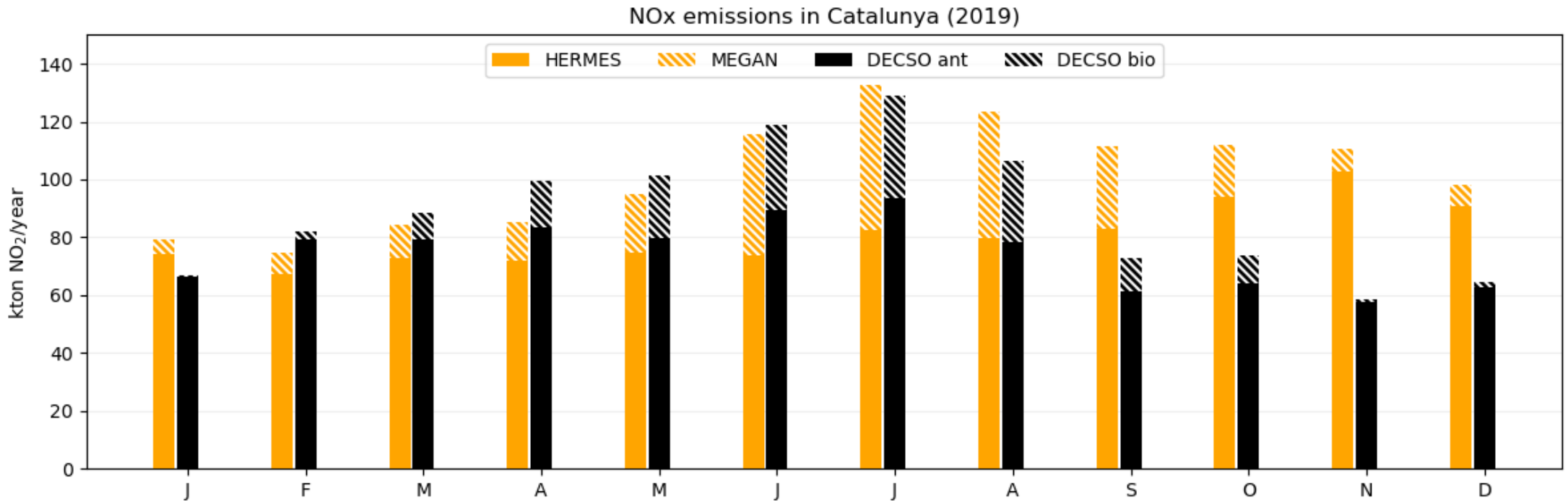


Comparison of NOx emissions over Catalonia

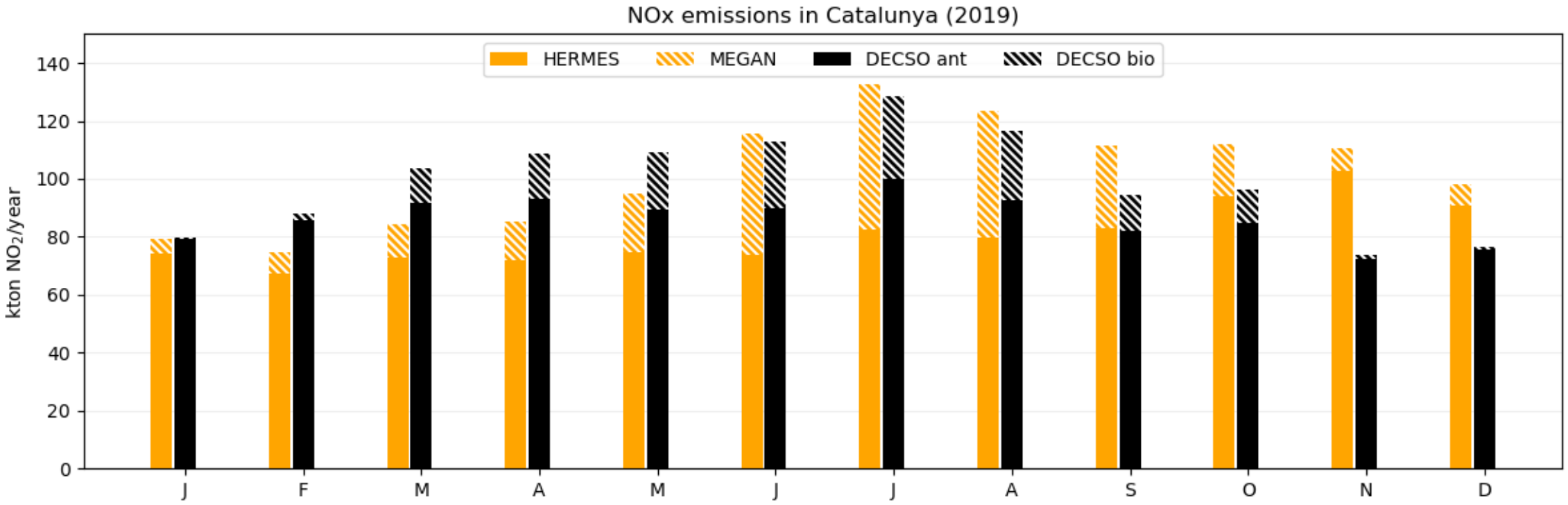
satellite-derived: DECSO anthropogenic and biogenic

vs.

bottom-up: HERMES (anthropogenic) and MEGAN (biogenic)



Latest result for the new DECSO version 6.0
(includes CHIMERE v2020r3)



Summary

NOx emissions

- Improved results from superobservations of new TROPOMI NO2 retrievals (PAL version).
- Daily NOx emissions over Europe on a resolution of 15-20 km.
- Zoom-in version on a 0.05 degree resolution demonstrated.
- Emissions derived for anthropogenic, biogenic (agricultural, forest) and maritime source sectors.
- Good agreement with HERMES/MEGAN of spatial locations and absolute regional emissions in 2019.
- Seasonal cycle and certain hotspots need further verification.

This work is partially funded by the SEEDS project of the EU

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Funded by the European Union