Local scale modelling across Europe with uEMEP

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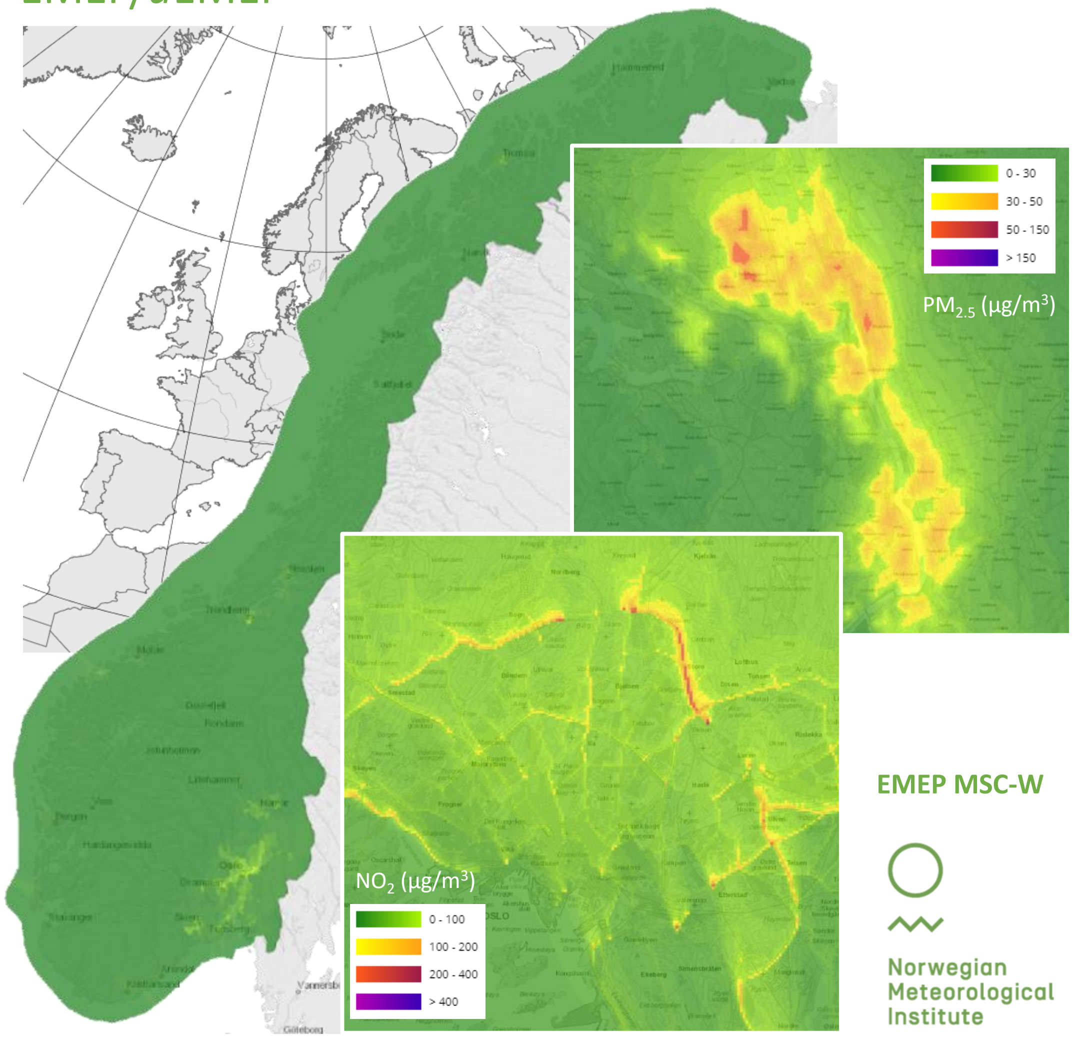
EMEP/*u*EMEP



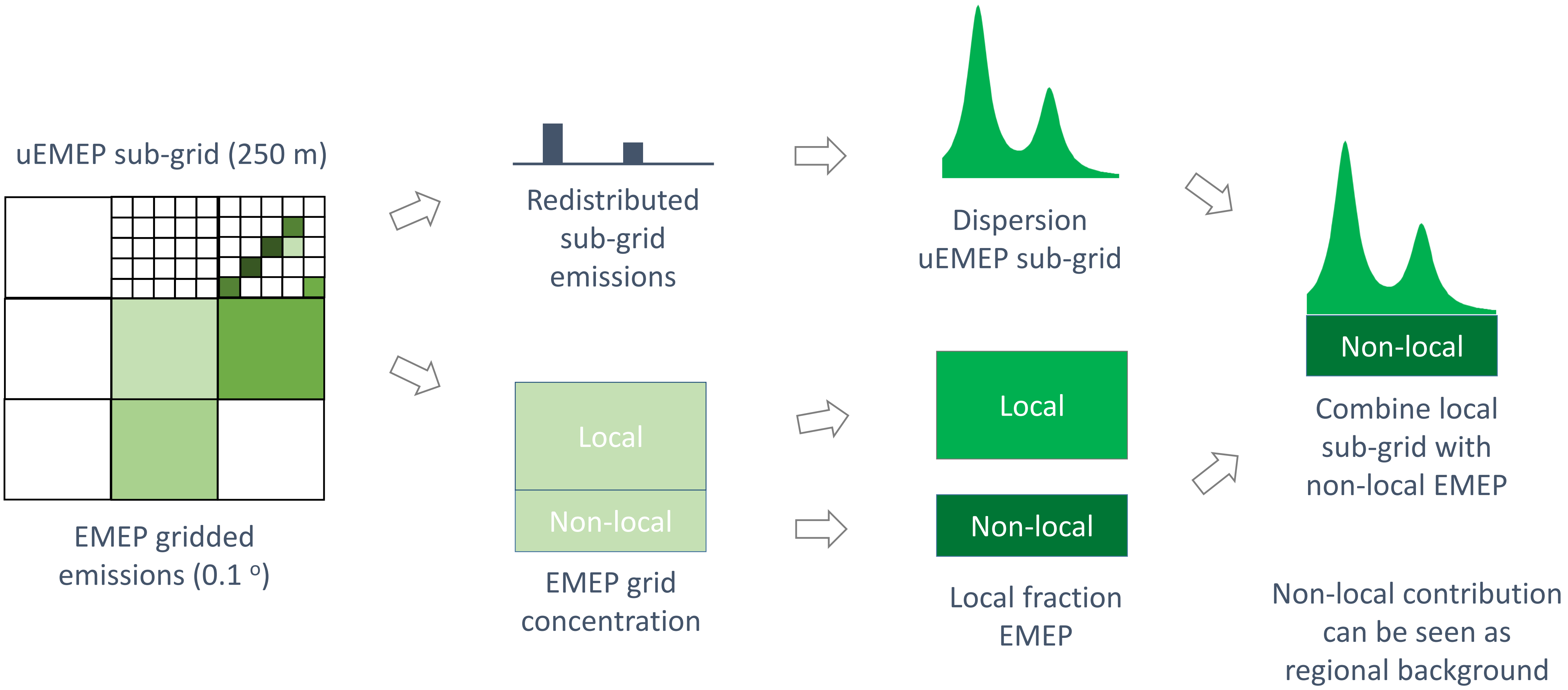
EMEP MSC-W

Norwegian Meteorological Institute

What is uEMEP?

- uEMEP (urban EMEP) is an extension of the EMEP MSC-W model used to downscale EMEP to around 100 m
- It can be inserted anywhere in the EMEP domain and deals with double counting of emissions by utilizing the ‘local fraction’ output from EMEP
- uEMEP dispersion is calculated using a Gaussian dispersion model
- It can be run on hourly data (Norwegian forecast) or can calculate annual means using a rotationally symmetric dispersion kernel (European application)
- Emissions can be provided in two ways. Using independent sub-grid emissions (Norwegian forecast) or by redistributing EMEP gridded emissions using proxy emission data (Europe)
- Source contributions are calculated for each downscaled sector and pollutant
- Maps are made between 50 m and 250 m resolution and calculations at individual receptor points are at 25 m

How does uEMEP downscaling work ?



Some points when downscaling

- The uEMEP 'local' downscaling calculation extends over a limited region. In the European application this is ± 0.1^o . The uEMEP calculations represent all sub-grid emissions within these regions
- Outside of this region, or for sectors that are not downscaled, EMEP provides the 'non-local' contribution
- Downscaling is limitted to primary emissions (NO_X is downscaled and converted to NO_2)
- The sub-grid traffic data are line sources so higher resolutions will better reflect the traffic contribution
- The sub-grid resolution of residential combustion (and other) proxy emissions is 250 m so any higher resolution calculations will not improve these contributions
- 250 m population data is used for exposure

European air quality downscaling

Method for the European application

http://emep.int/publ/emep2020_publications.html

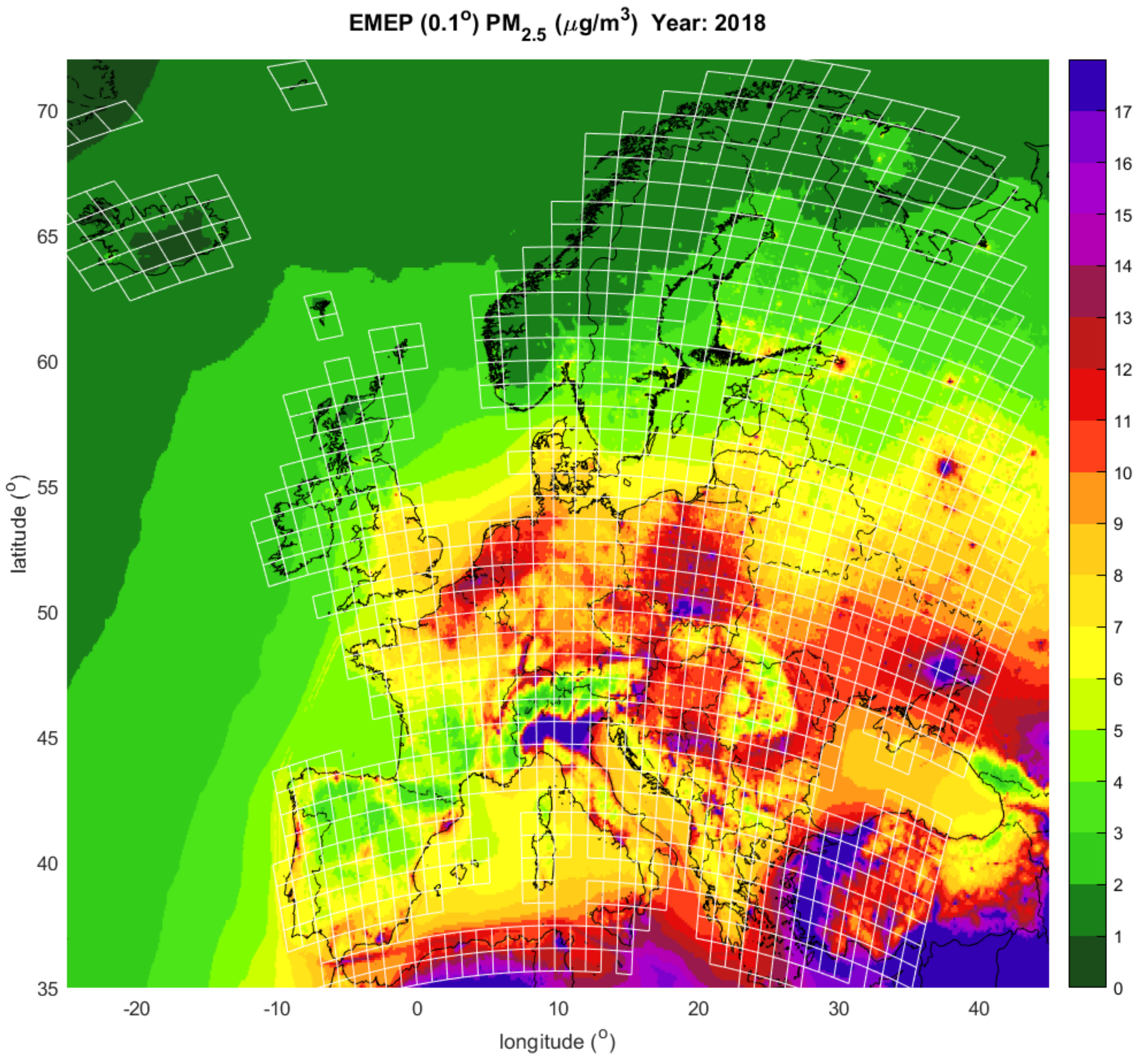
- EMEP MSC-W chemical transport model is used to calculate air quality at 0.1° x 0.1° in Europe for 2018 (as in 2020 EMEP report) including 'local fraction' in just a 5 x 5 grid region
- EMEP 0.1° emissions are used but GNFR3 (residential combustion) is replaced with TNO GNFR3 emissions that include condensables
- Only annual mean concentrations are calculated by uEMEP

- Emission proxies used to redistribute gridded EMEP emissions :
  - Traffic emissions are downscaled using Open Street Maps as proxy (weighting by road category)
  - Residential combustion (GNFR3) downscaled using 250 m population as proxy
  - Shipping emissions downscaled using AIS based shipping emissions
  - All these proxies are global datasets

- Downscaled concentration maps for Europe are calculated at 250 and 100 m and at Airbase station positions at 25 m

Tiling

- uEMEP is calculated on separate individual tiles in order to efficiently process the calculations
- At 250 m resolution there are 199 tiles
- At 100 m resolution there are 1097 tiles
- These are then fitted together when presenting results

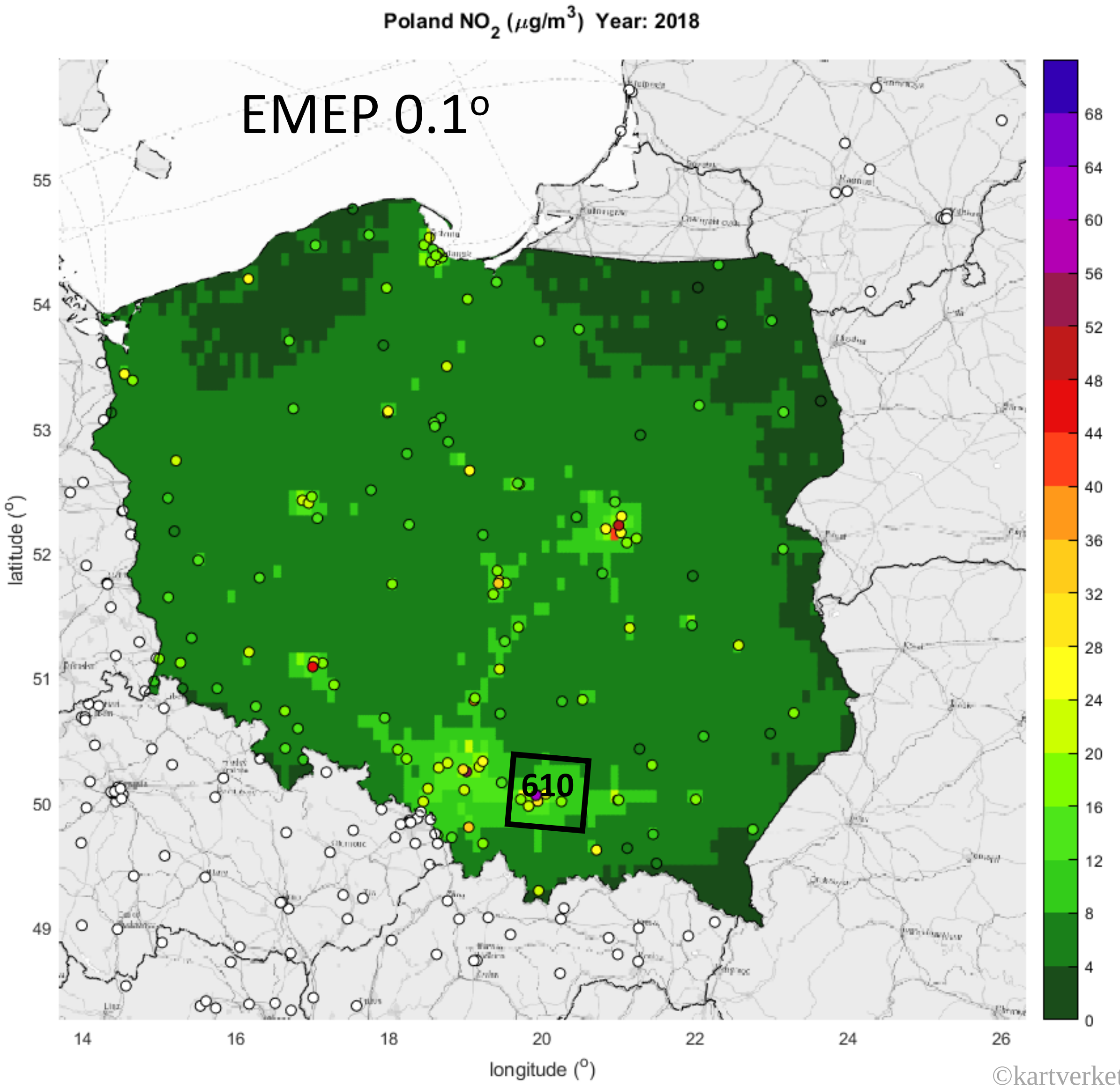


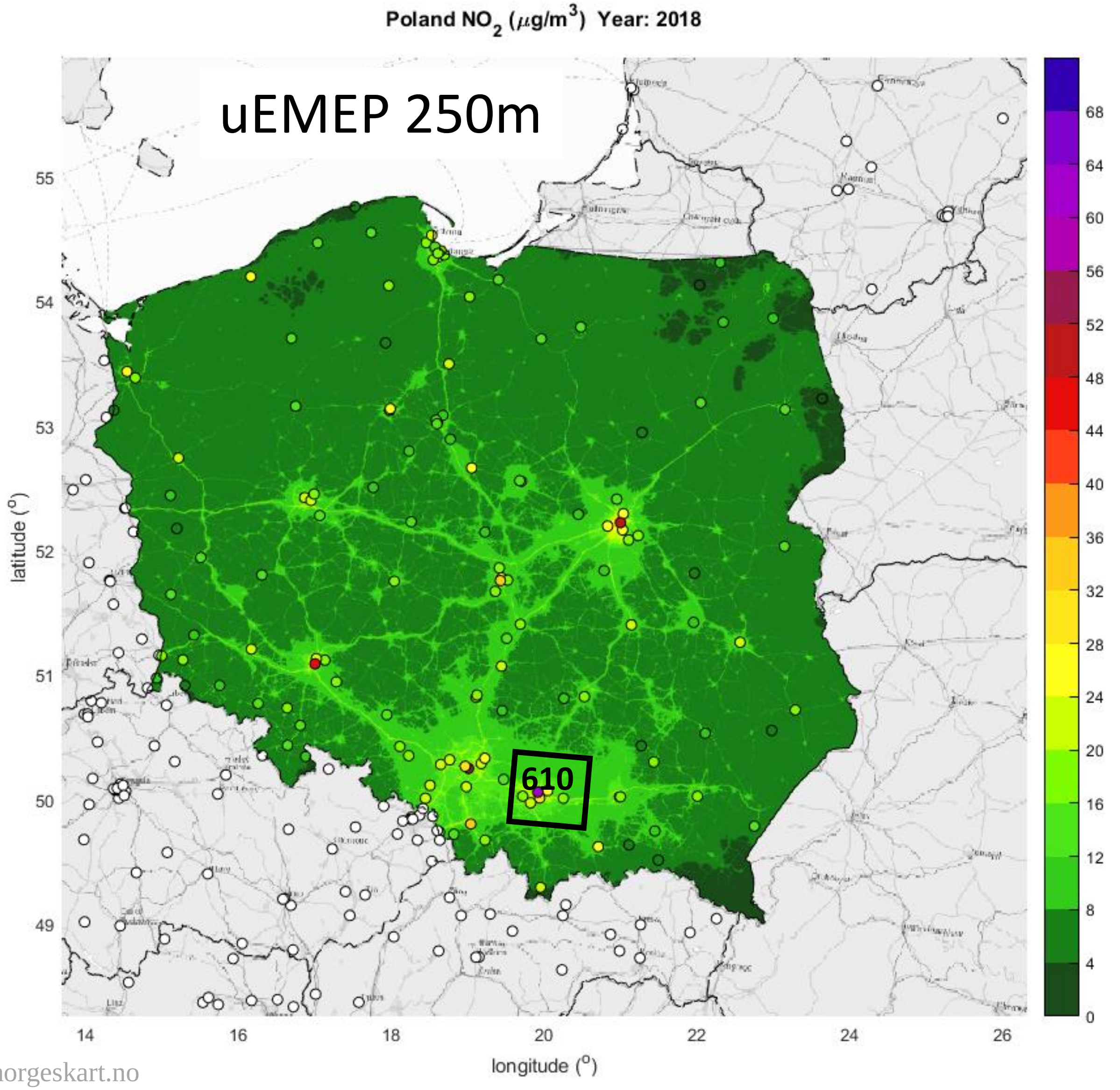
100 m resolution uEMEP tiles 100 x 100 km^2 each

Example maps

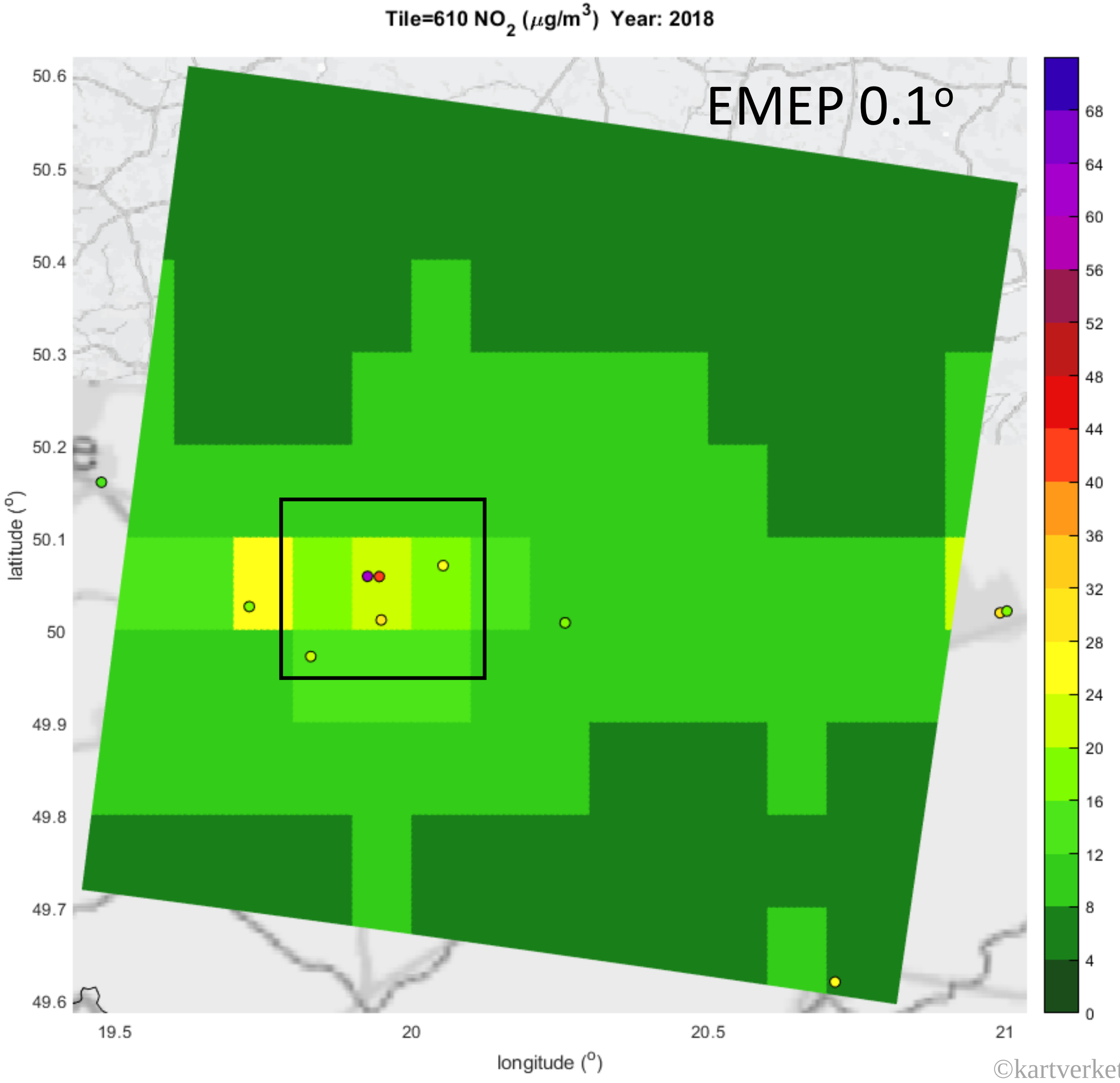
Poland and France

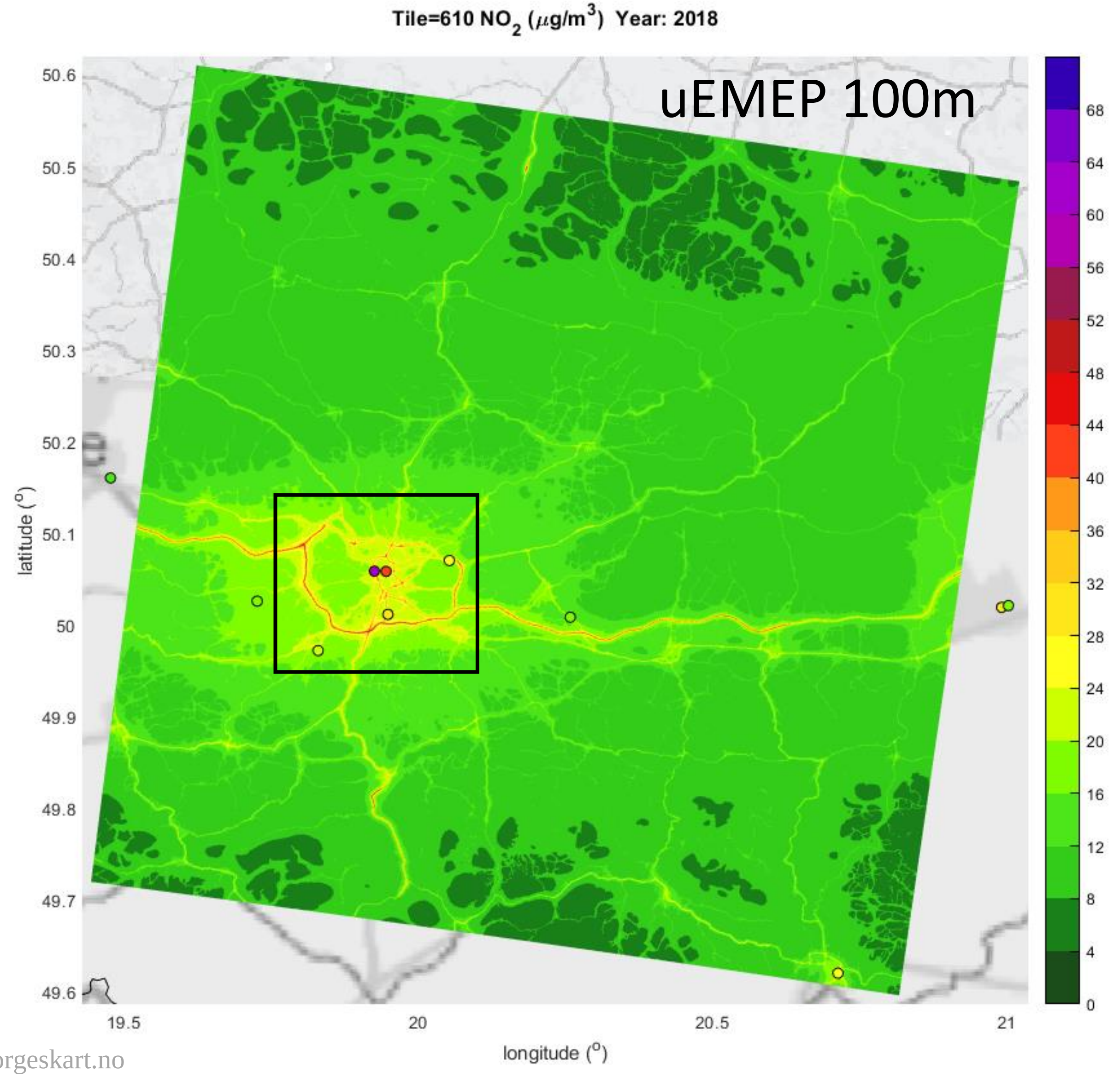
Poland NO_2 (2018)



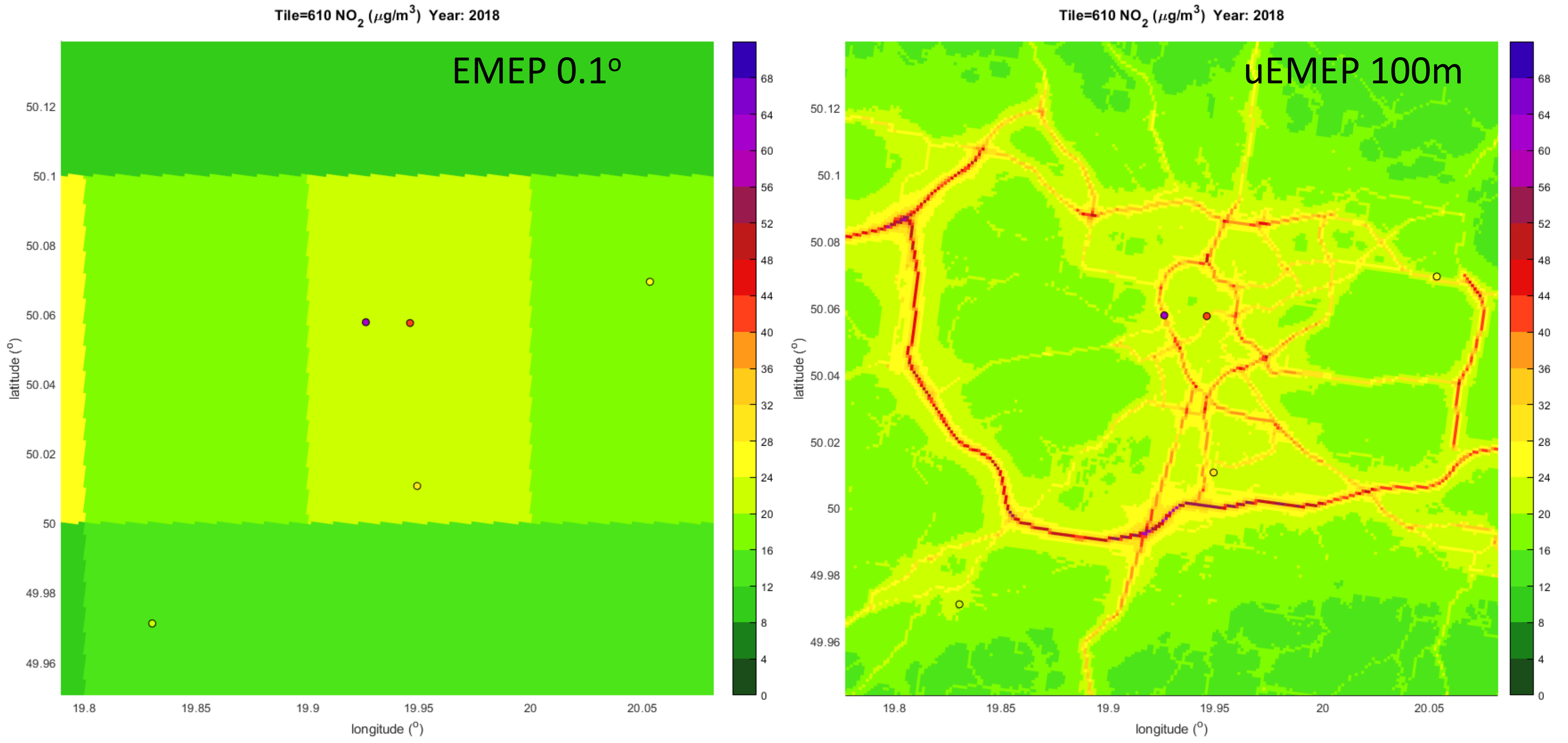


Tile 610 (Krakow) NO_2 (2018)

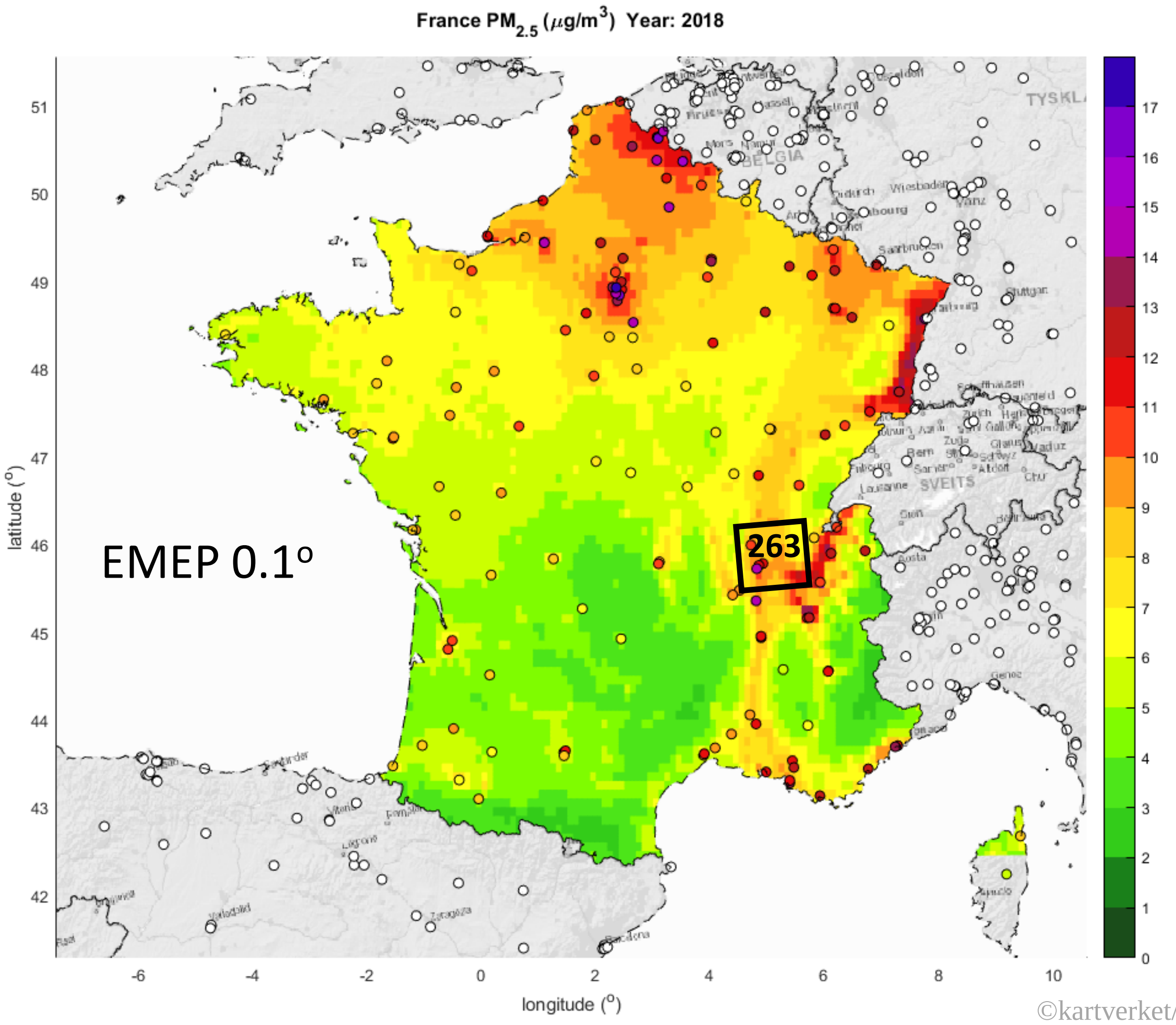


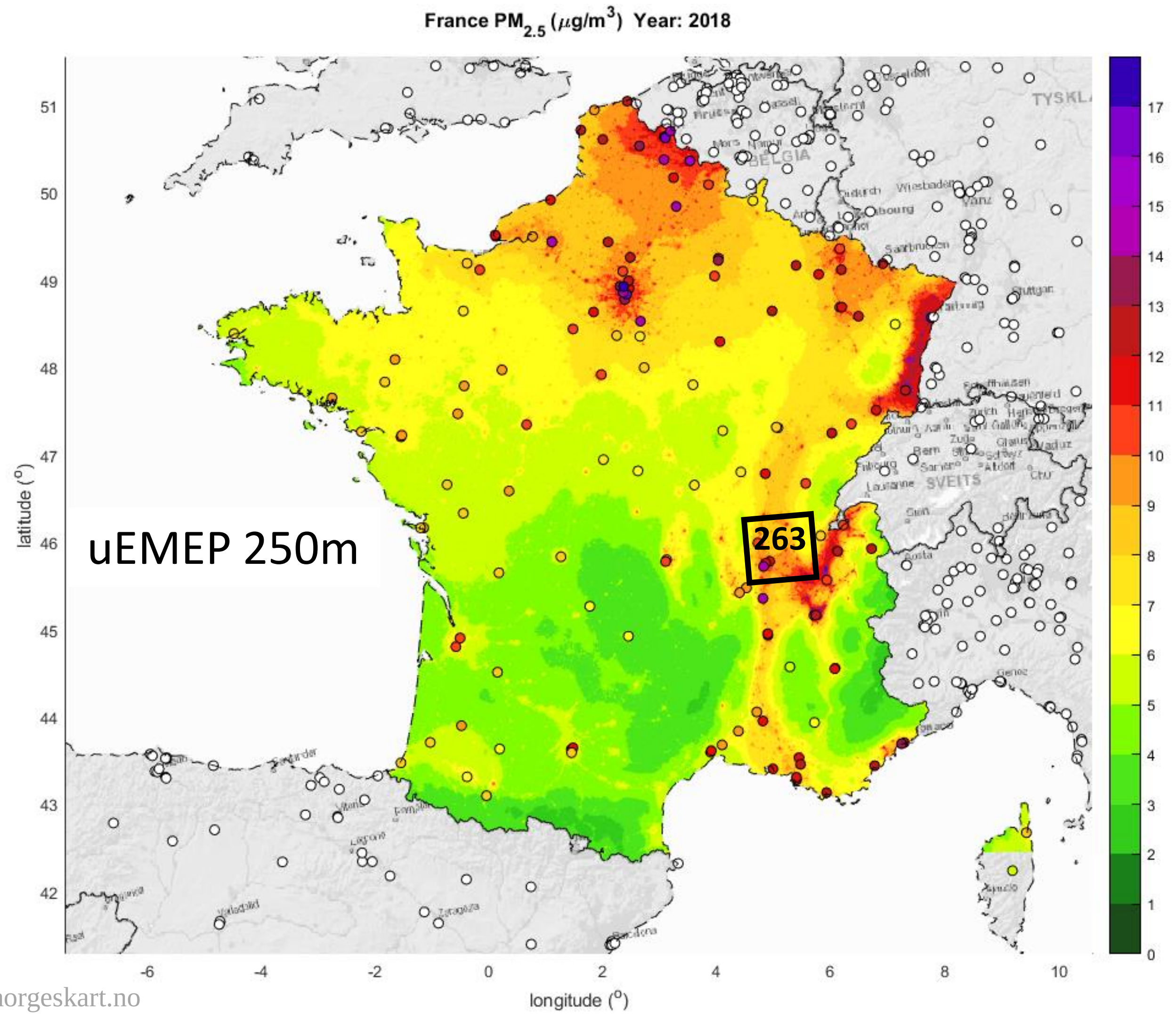


Krakow NO_2 (2018)

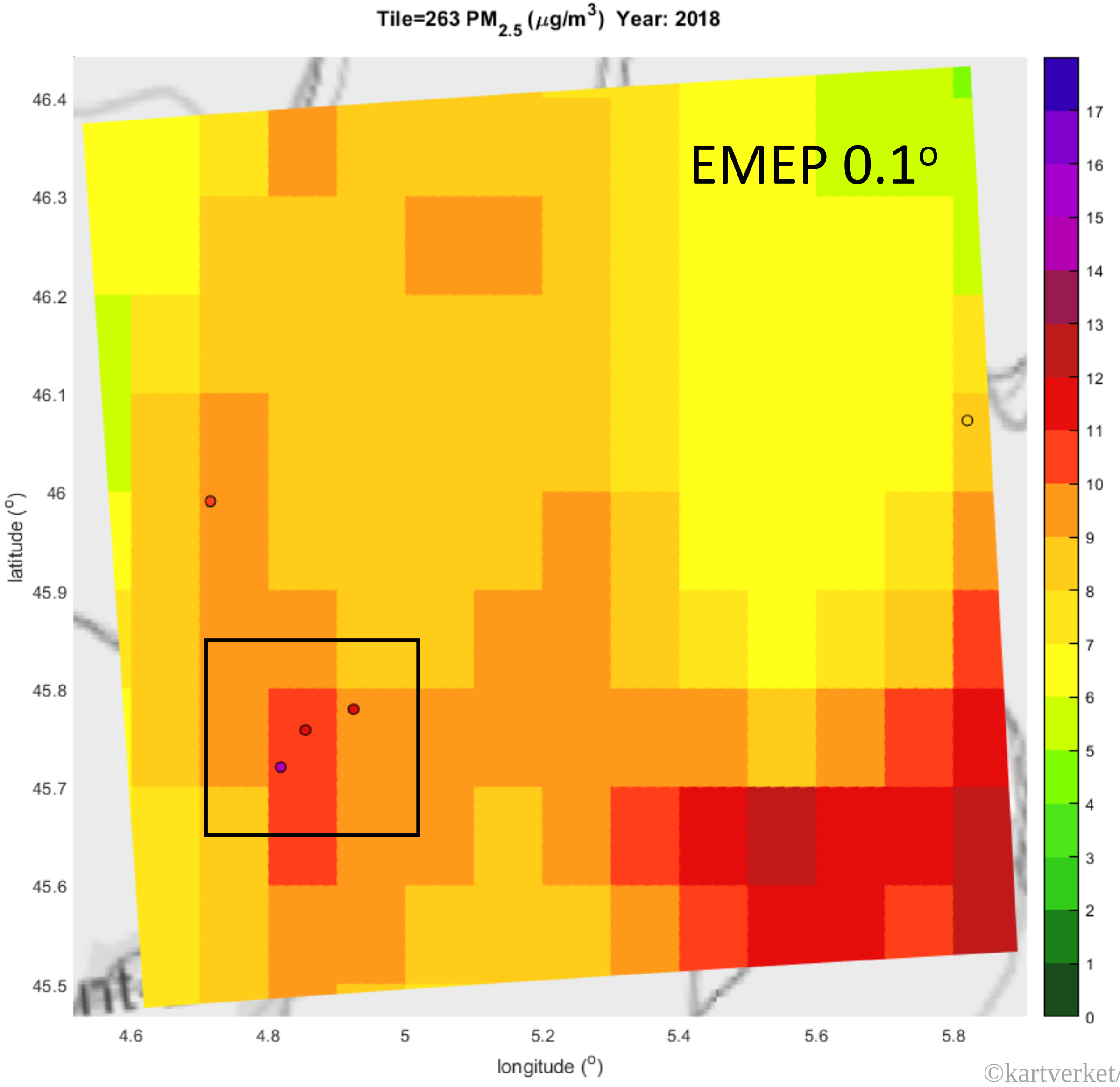


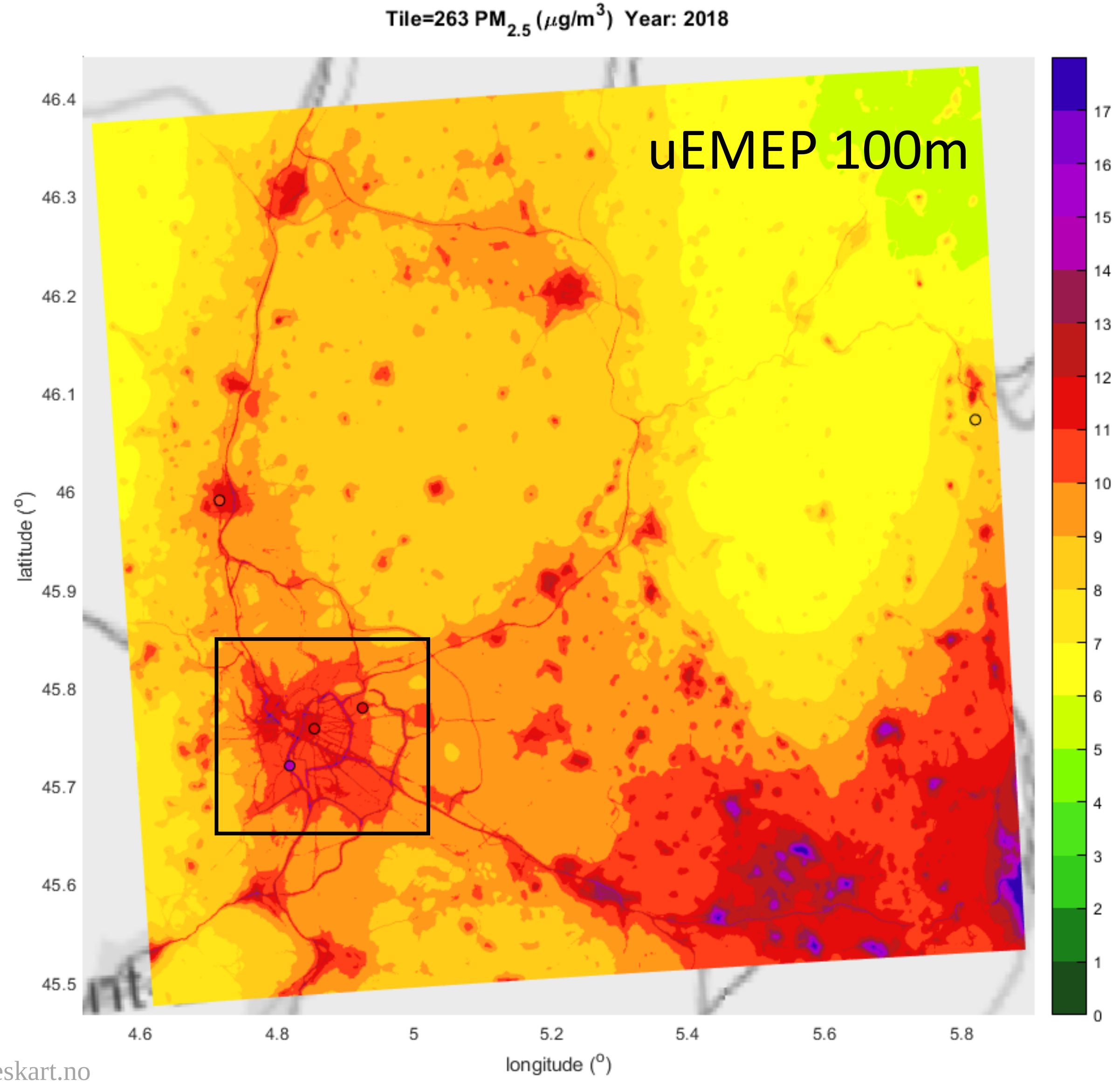
France $PM_{2.5}$ (2018)



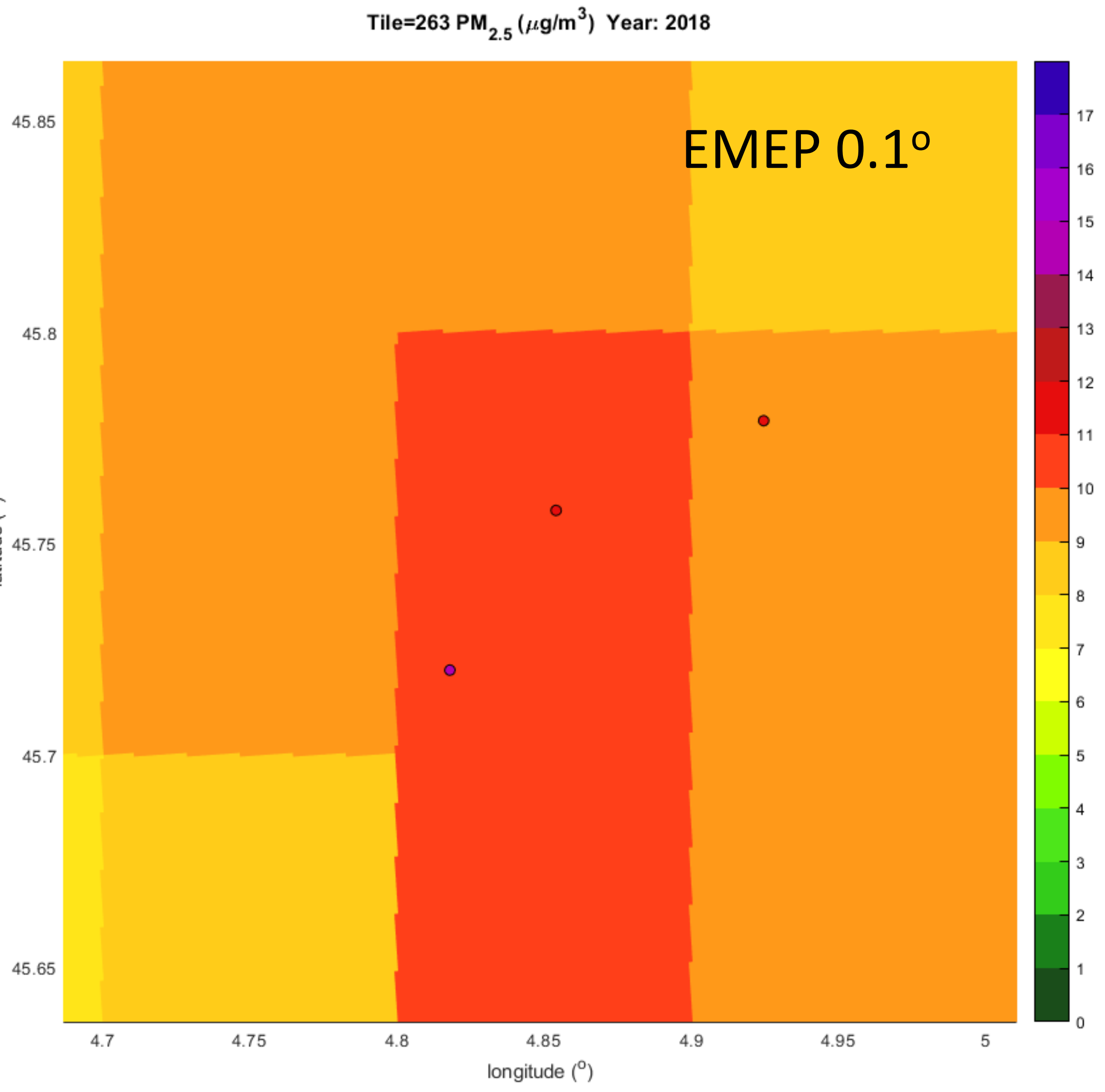


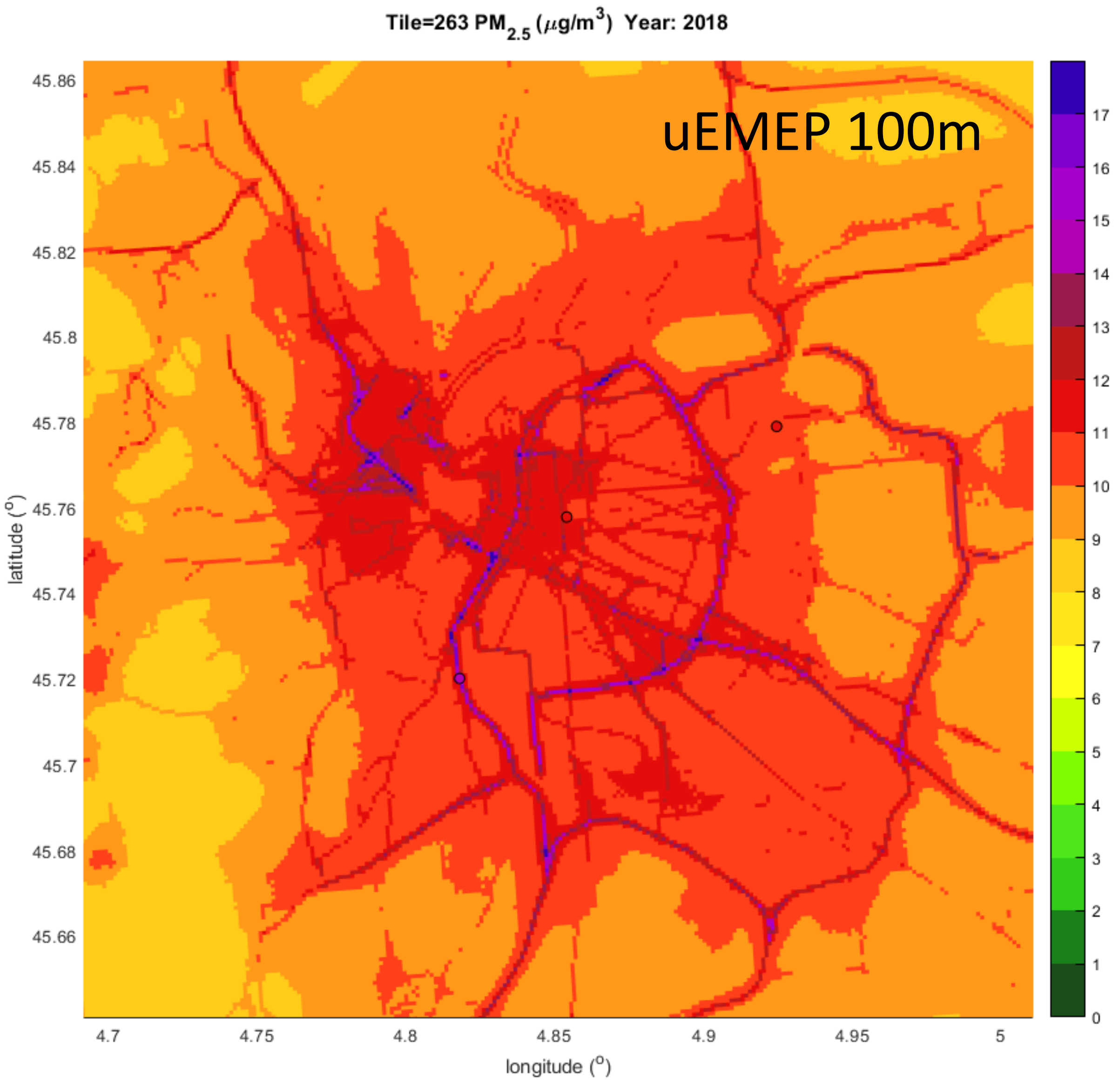
Tile 263 (Lyon) $PM_{2.5}$ (2018)





Lyon $PM_{2.5}$ (2018)

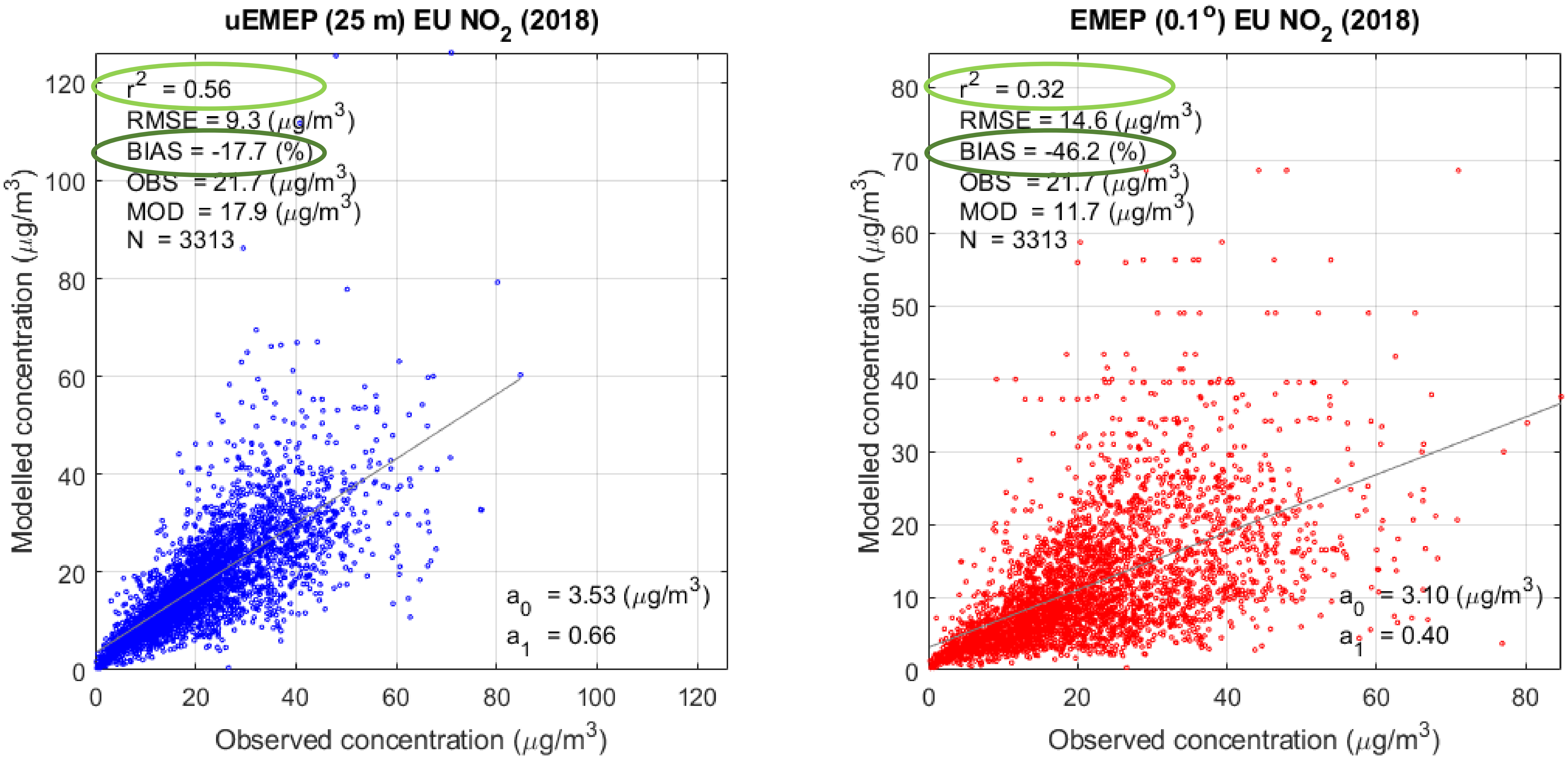




Validation for NO_2 and $PM_{2.5}$

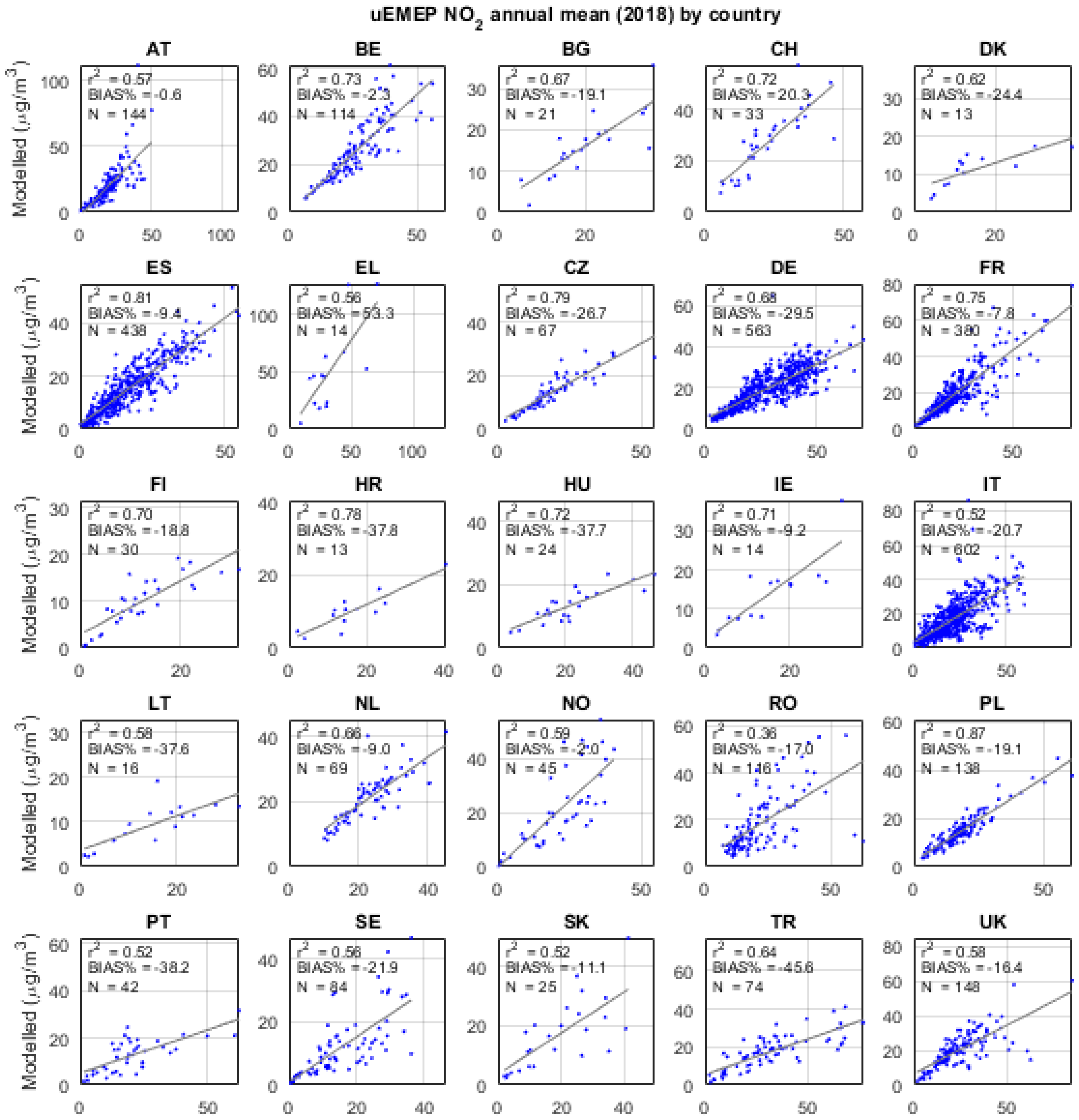
all Airbase stations

Validation for NO_2 in Europe (3313 stations)

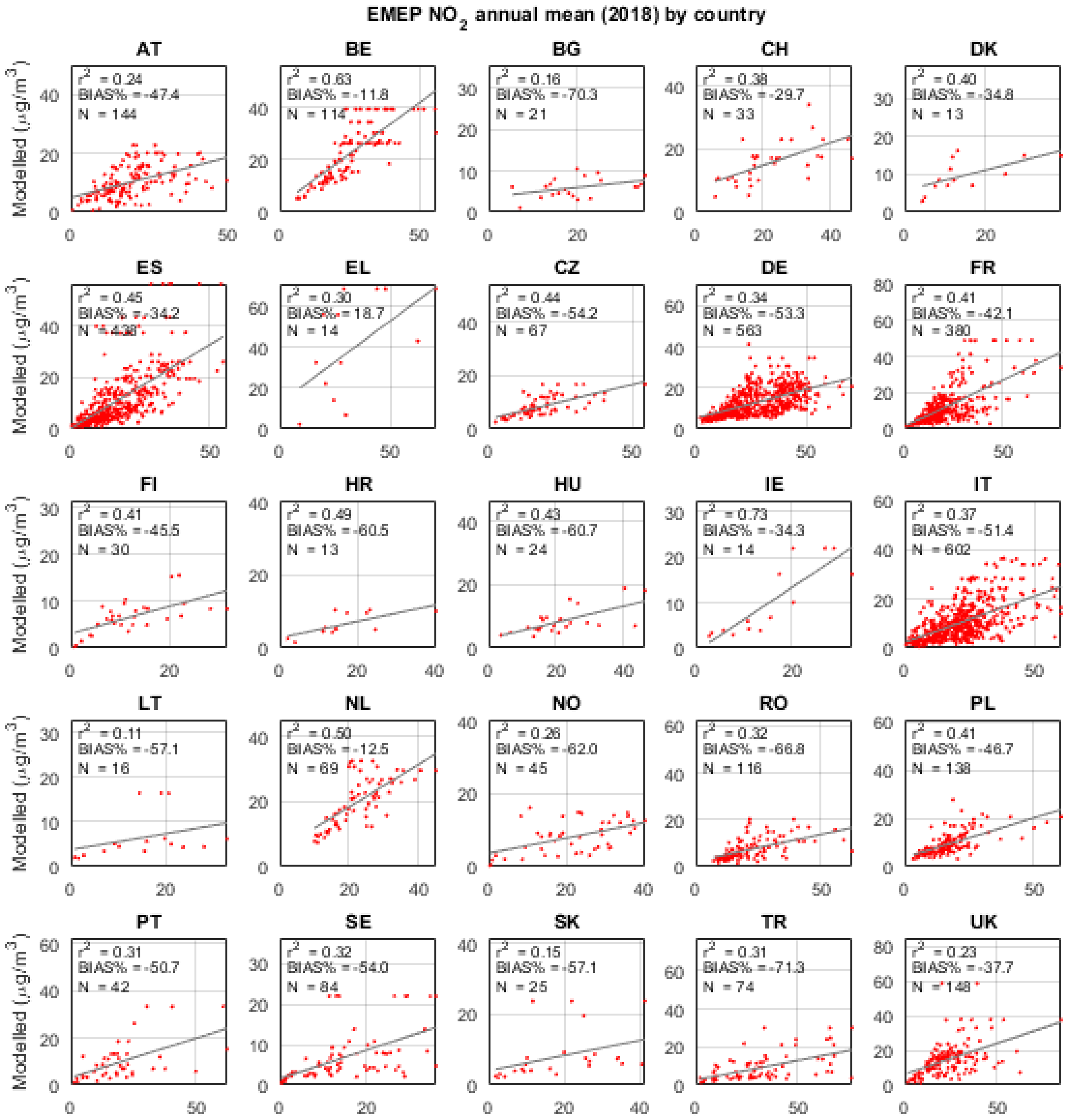


Validation for NO_2 in Europe (3313 stations)

Modelled

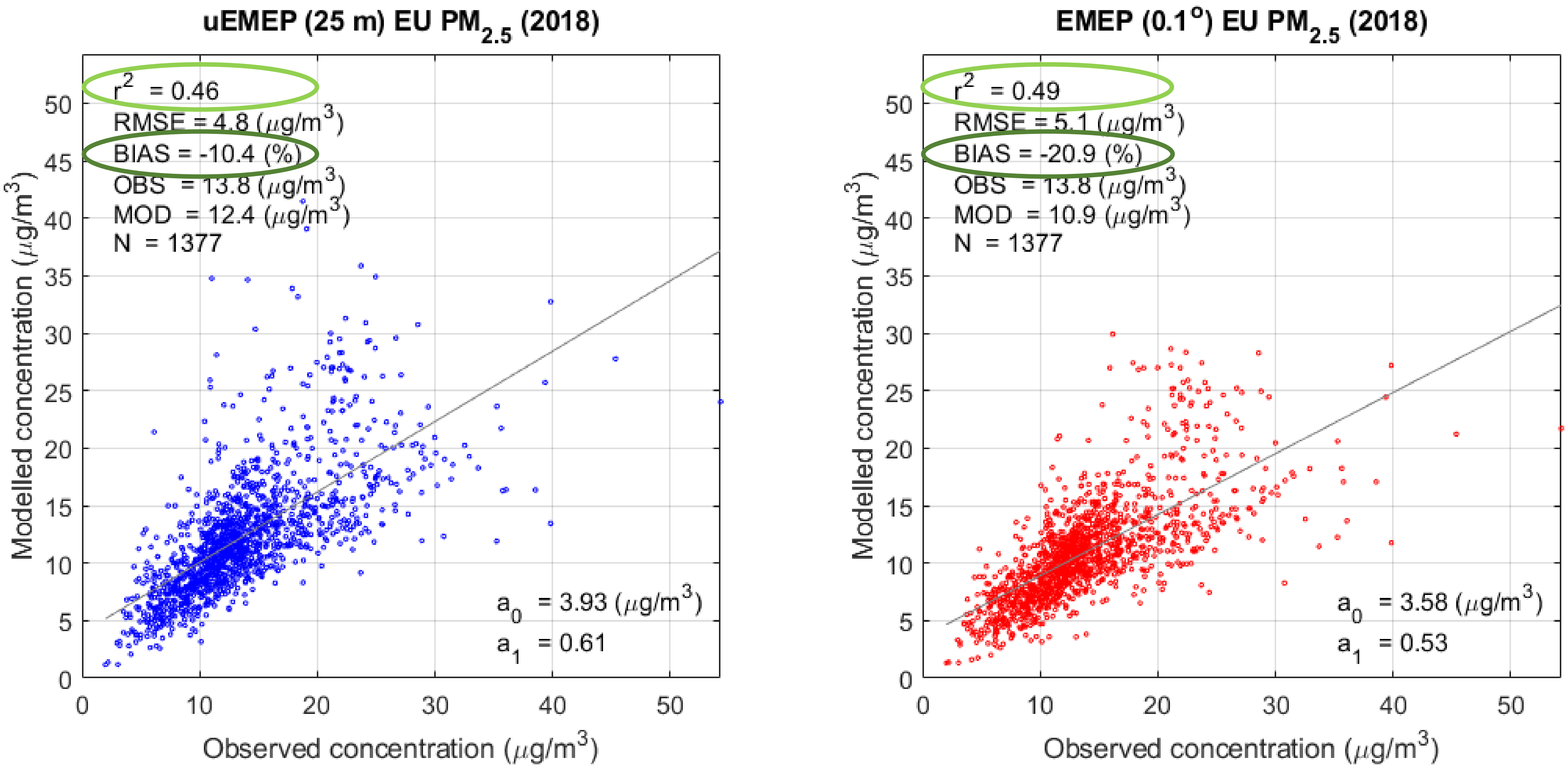


Observed



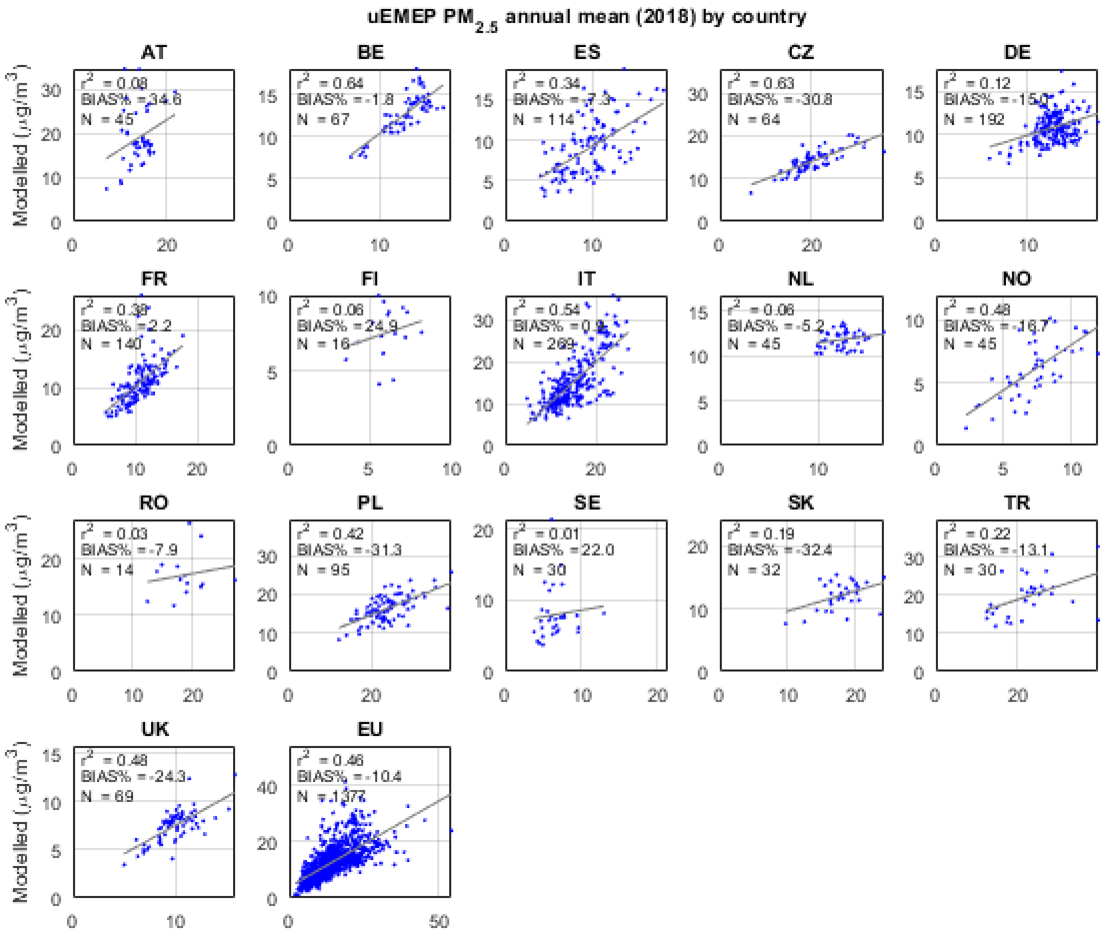
Observed

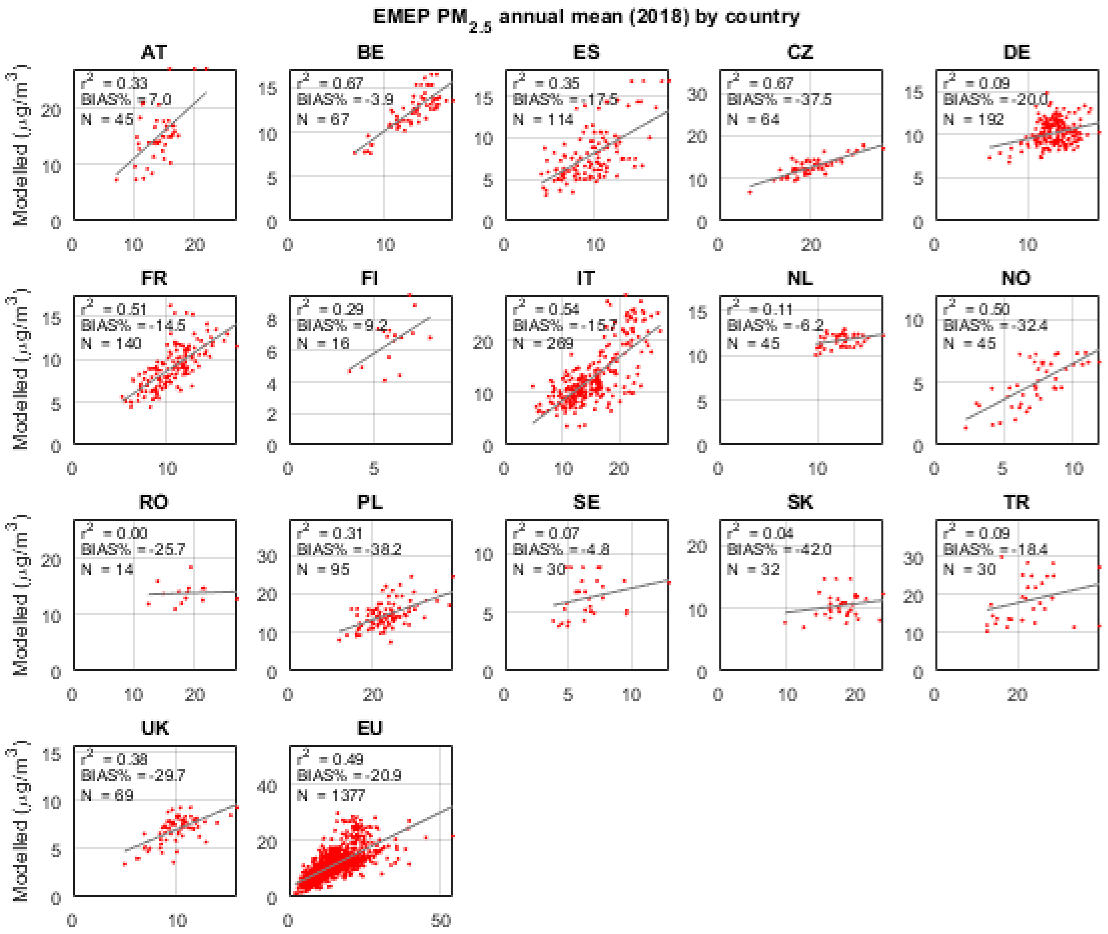
Validation for $PM_{2.5}$ in Europe (1377 stations)



Validation for $PM_{2.5}$ in Europe (1377 stations)

Modelled





Observed

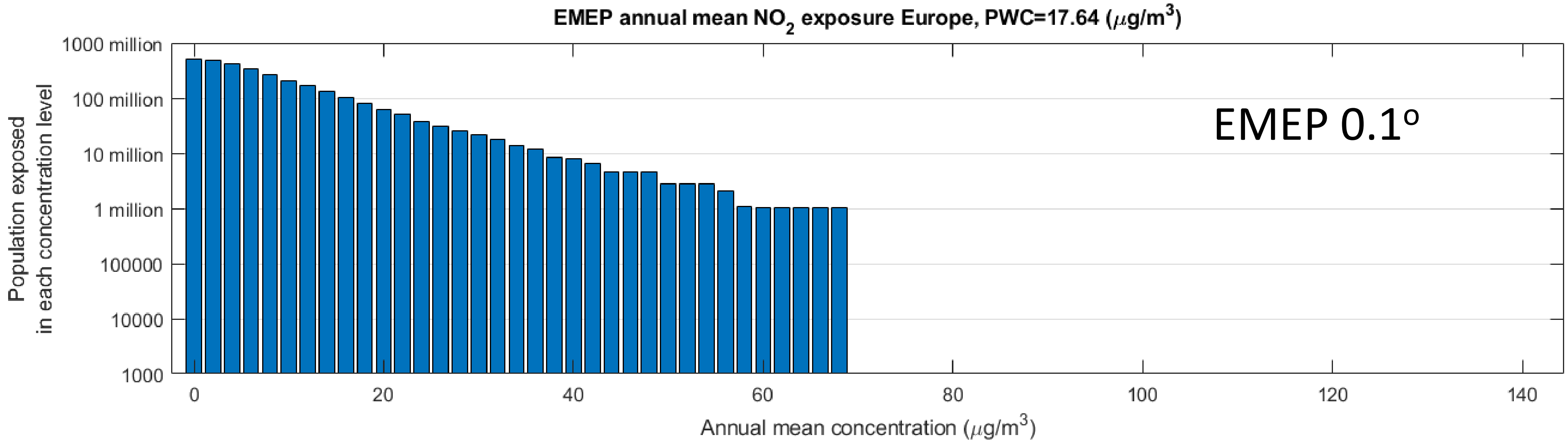
Observed

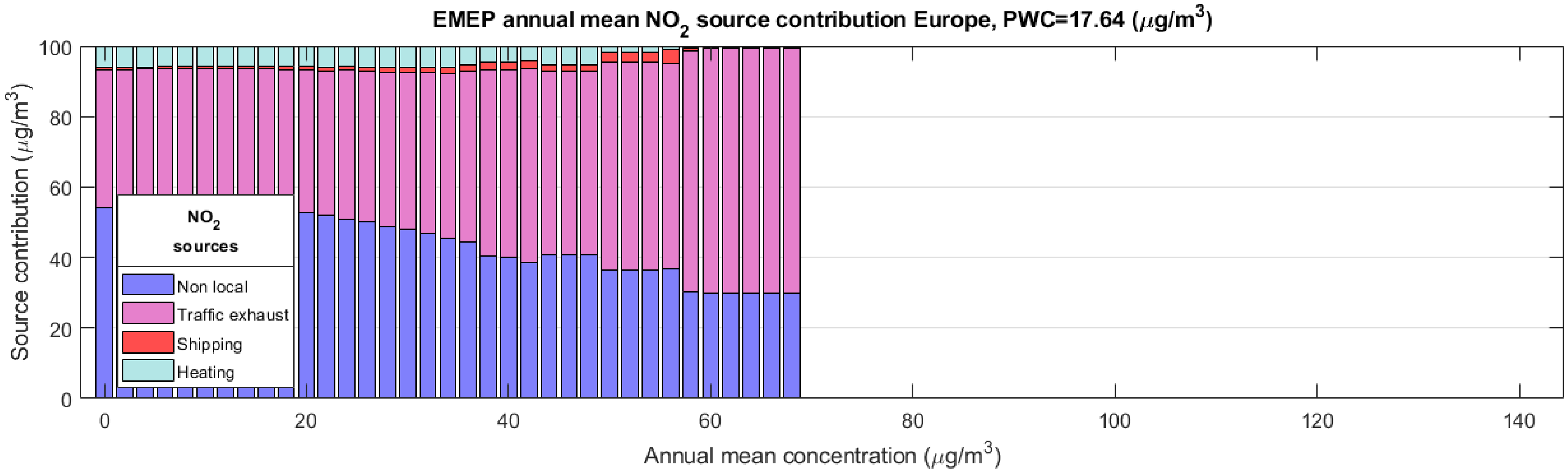
Summary of European downscaling validation

- Downscaled NO_2 concentrations are still generally lower than observed but this varies from country to country
  - uEMEP Bias = -17% compared to -46% for EMEP
- Spatial correlation for NO_2 is significantly improved with downscaling in all countries
  - All stations individually in Europe: r^2=0.56 compared to r^2=0.32 for EMEP
  - Average country: r^2=0.65
  - Variability between countries, probably due to reported emissions, reduces the European r^2
- Downscaled $PM_{2.5}$ concentrations are generally still lower than observed
  - uEMEP Bias = -10% compared to -21% for EMEP
- Spatial correlation for $PM_{2.5}$ is improved in less than half the countries with downscaling
  - uEMEP r^2=0.46 compared to r^2=0.49 for EMEP for all of Europe
- Still work to be done here

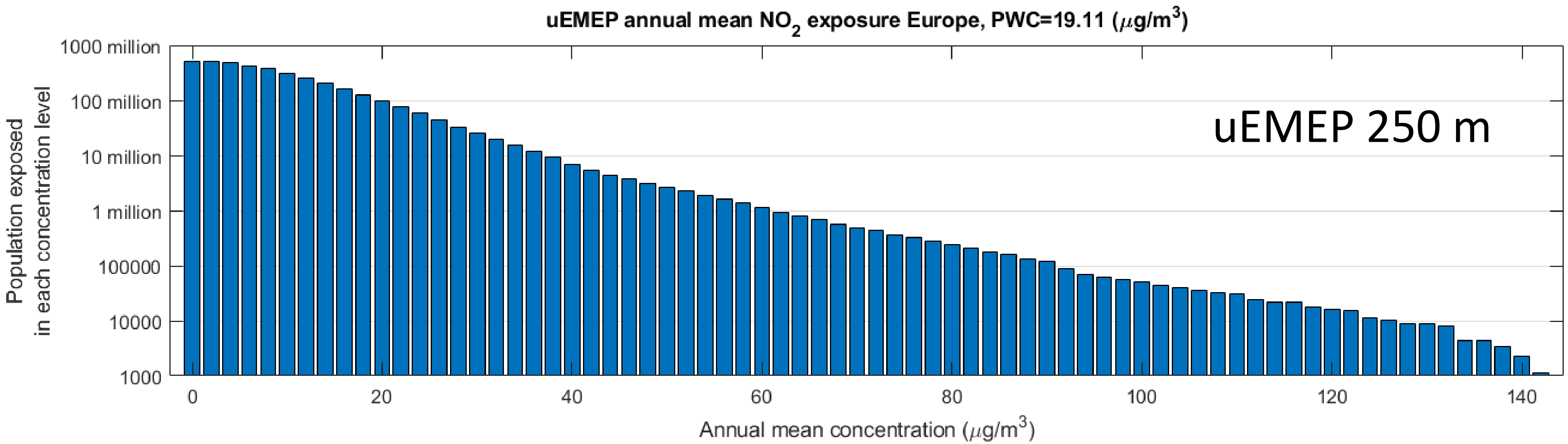
Exposure

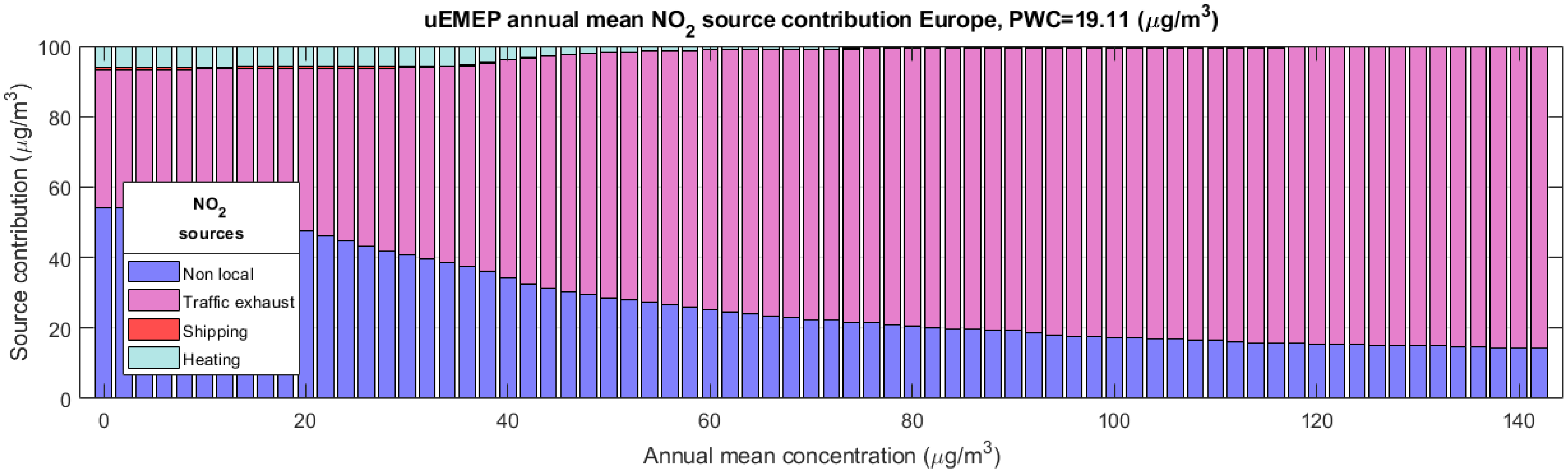
Calculated exposure distribution for NO_2 (EU28+EFTA)



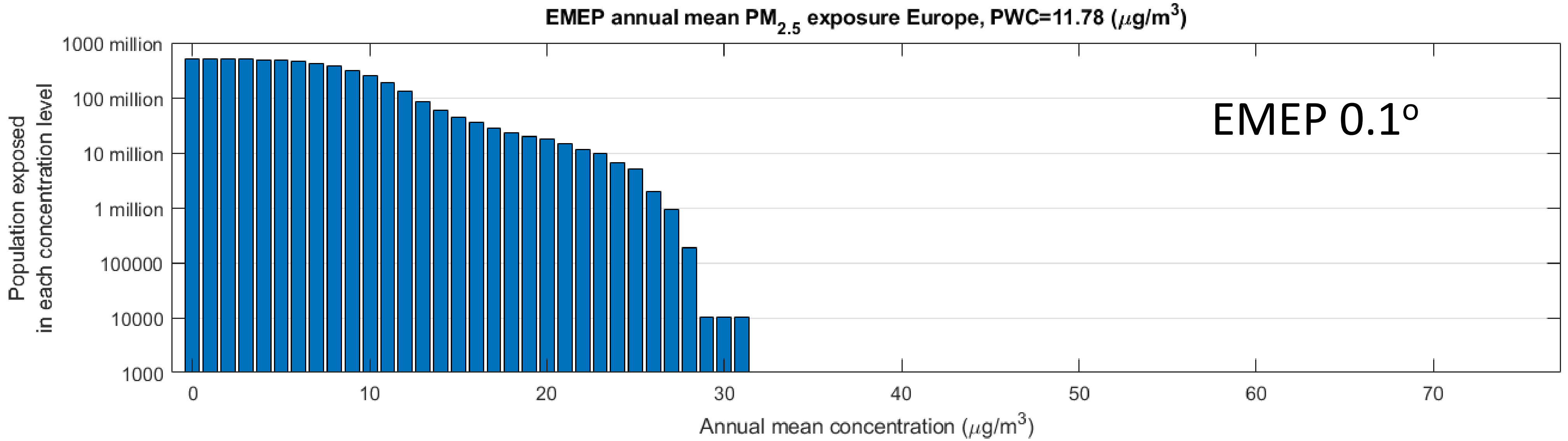


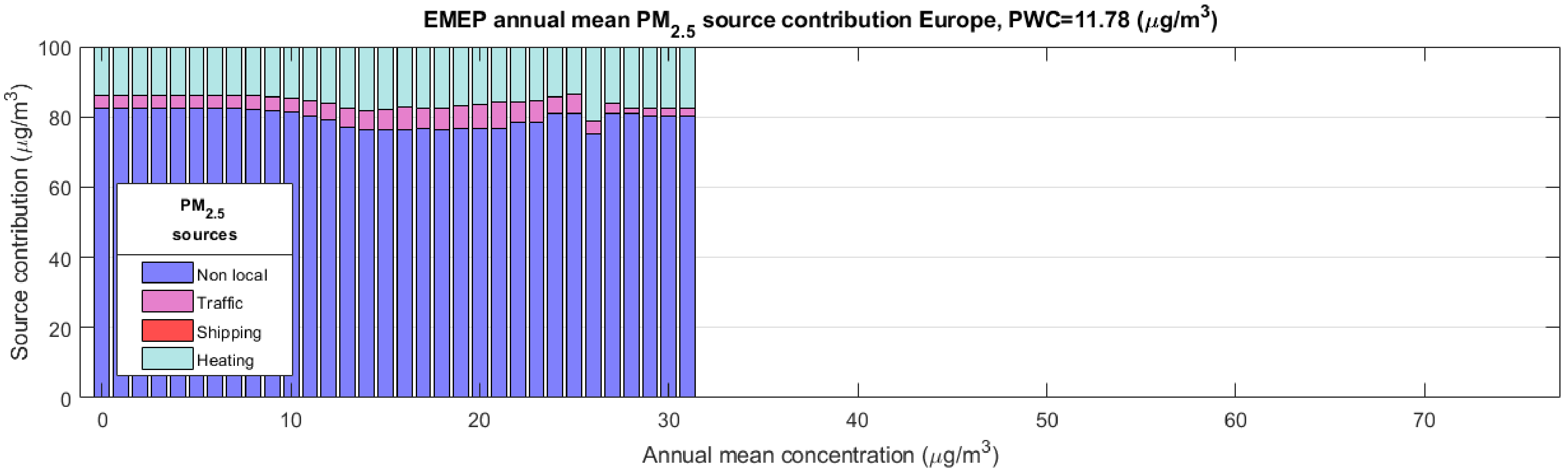
Calculated exposure distribution for NO_2 (EU28+EFTA)



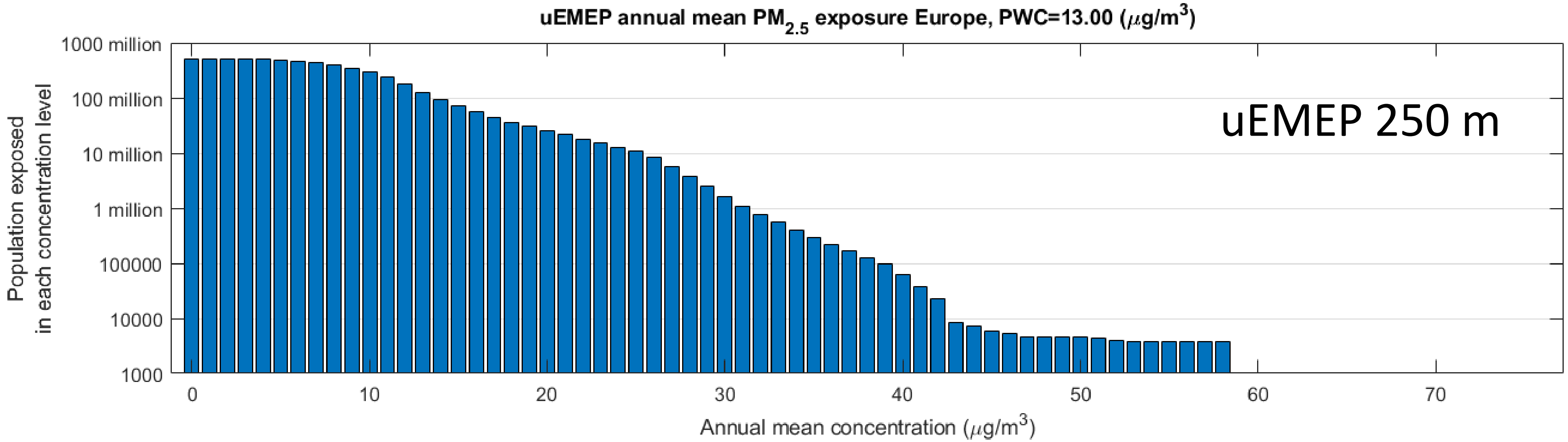


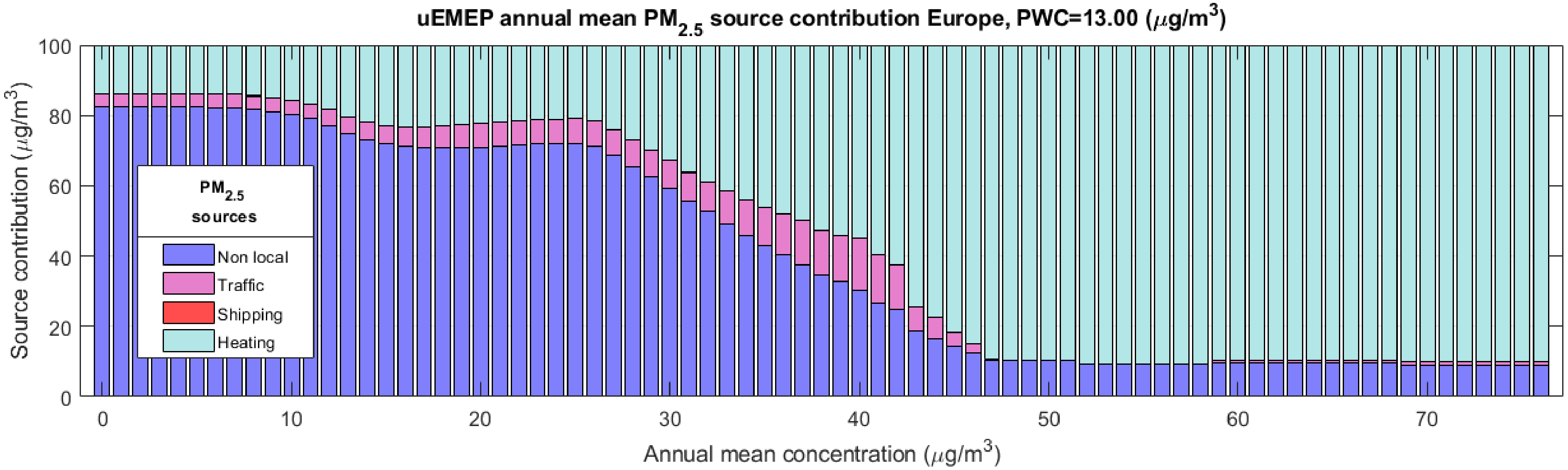
Calculated exposure distribution for $PM_{2.5}$ (EU28+EFTA)





Calculated exposure distribution for $PM_{2.5}$ (EU28+EFTA)





Summary of European exposure calculations

Total population EU28+EFTA = 507 million

Annual mean $PM_{2.5}$	EMEP	uEMEP
Population weighted concentration (µg/m^3)	11.8	13.0
Population exposed (million)		
> 10 µg/m^3	255 (50 %)	300 (59 %)
> 20 µg/m^3	17 (3.4 %)	26 (5.1 %)
> 25 µg/m^3	5.1 (1.0 %)	10.5 (2.1 %)

Annual mean NO_2	EMEP	uEMEP
Population weighted concentration (µg/m^3)	17.6	19.1
Population exposed (million)		
> 40 µg/m^3	7.9 (1.6 %)	6.9 (1.4 %)
> 60 µg/m^3	1.0 (0.20 %)	1.1 (0.22 %)
> 80 µg/m^3	0 (0 %)	0.21 (0.04 %)

NB: For 2016 EEA gives 4% > 25 µg/m^3 for $PM_{2.5}$ and 3% over 40 µg/m^3 for NO_2

Summary of European exposure calculations

$PM_{2.5}$

- Most important contributor in the downscaling is residential combustion
- Using population as a proxy means that emissions are moved towards where people live, increasing concentrations there and reducing them where they do not live
- Significant increase in exposure as a result

NO_2

- Most important contributor in the downscaling is traffic
- Using OSM as a proxy can move the emissions away from the population since people often do not live near major roads
- Exposure can be less with downscaling because of this
- Extreme values of exposure can be captured with downscaling

Relevance for EPCAC

Advantages of uEMEP in Europe

- Gives significant improvement for NO_2 concentrations and is directly comparable with, but should not be as good as, national models (e.g. Norway, The Netherlands)
- Redistribution of EMEP emissions for the local uEMEP calculations means that total emissions are consistent through all scales
- Provides a consistent modelling methodology across Europe, covering all cities, large or small and provides insight into differences between countries and reported country emissions
- Provides source contributions for downscaled sectors that are emitted locally, allowing the impact of local measures to be quickly assessed by post-processing
- In combination with EMEP source receptor calculations using ‘local fractions’ uEMEP/EMEP can provide source contributions across all scales
- The non-local contribution from EMEP, using the ‘local fraction’ calculation, is suitable as regional background for other model studies (option A)
- Can provide a reference/benchmark for EPCAC European city studies

Disadvantages of uEMEP in Europe

- Does not show improvement in spatial correlation for PM but does reduce negative bias. Room for improvement in the uEMEP proxy data and/or the EMEP emission data
- Uses basic proxy data to redistribute emissions that are globally available. Local modelling should have better high resolution emission data and hence results (as seen in Norway)
- Can only downscale primary emissions
- Annual mean concentrations do not provide information on percentiles. Hourly calculations for all of Europe at 100 m are computationally prohibitive but for individual cities this is possible.

Documentation, data and models

- **Regional scale model:** EMEP MSC-W model rv4.34 (0.1° x 0.1°)
  - https://github.com/metno/emep-ctm
- **Downscaling model:** uEMEP v6 (250 – 25 m)
  - https://github.com/metno/uEMEP
- **Regional scale emissions:** EMEP 0.1^{o} with GNFR3 replaced by TNO Ref2 emissions including condensables
  - https://www.ceip.at/webdab-emission-database
- **Downscaling population data:** GHS-POP, Global Human Settlement-Population, (9 arcsec)
  - https://ghsl.jrc.ec.europa.eu/ghs_pop2019.php
- **Downscaling traffic data:** Open street maps
  - https://www.openstreetmap.org/
- **uEMEP model description and Norwegian application:**
  - https://gmd.copernicus.org/preprints/gmd-2020-119/
- **EMEP local fraction model description:**
  - https://gmd.copernicus.org/articles/13/1623/2020/
- **uEMEP application in Europe:** EMEP report 2020
  - https://emep.int/publ/reports/2020/EMEP_Status_Report_1_2020.pdf

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