The Norwegian air quality service: Model forecasting with uEMEP

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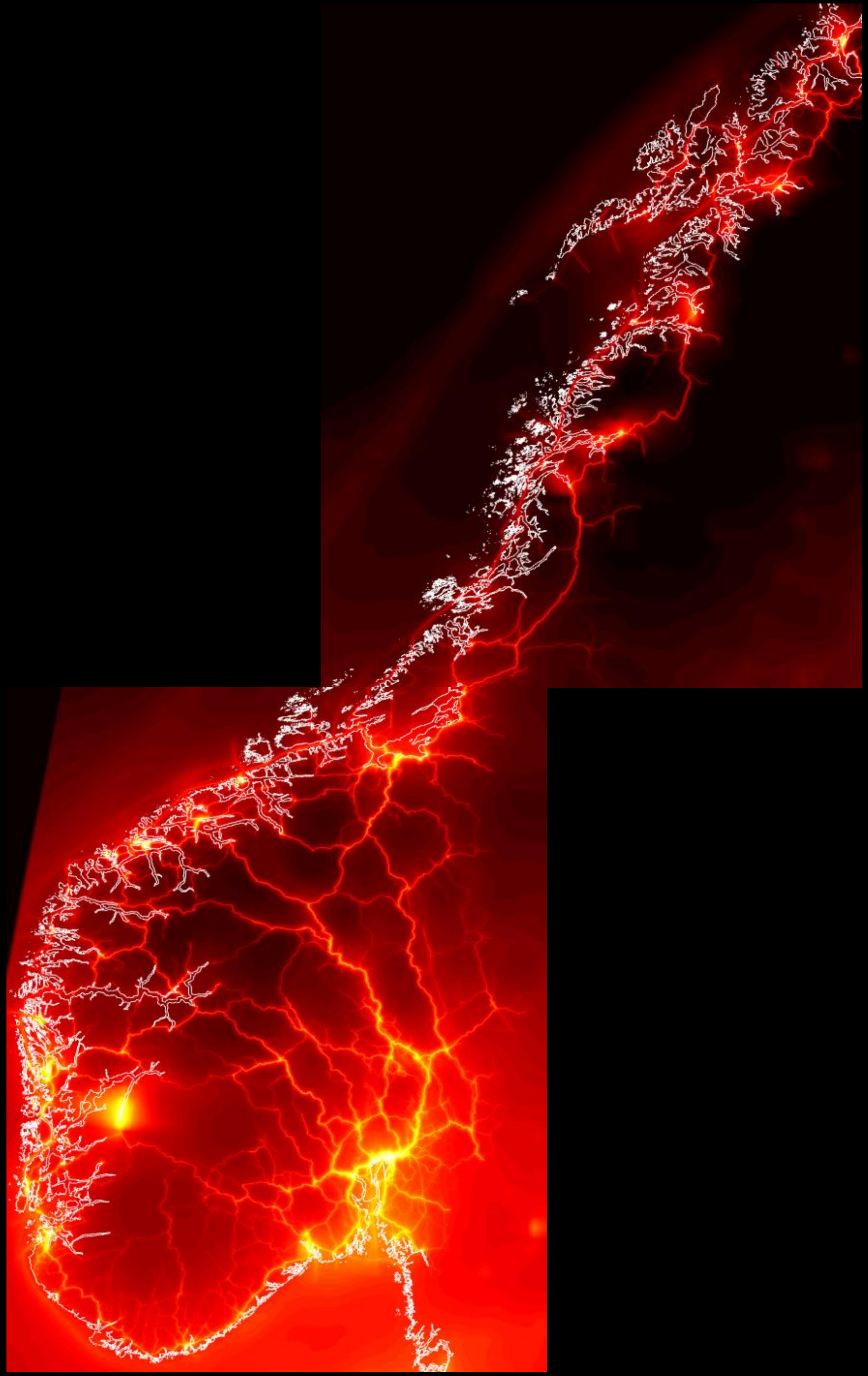
Ambition in Norway

- To provide a national air quality modelling system to support both local and national authorities in their air quality obligations
- The modelling system will be used, and be useful, for the following applications
  - **Air quality forecasting**
  - Short term air quality measures
  - Long term air quality planning
  - Providing information and awareness to the public



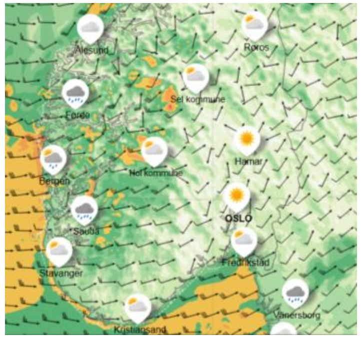
Content of this presentation

- Background
- Description of the forecast modelling system
- Emissions used in the forecasts
- Model implementation for forecasts
- Example forecast maps
- Comparison to measurements for 2017
- Other applications outside of Norway
- Summary

Background

What is needed in an air quality forecast?

- Meteorology
  - Meteorological models provide forecasts required for the air quality model
  - Important are wind speed and direction, atmospheric stability, mixing height and precipitation
  - An air quality forecast is no better than the meteorology it uses!



- Emissions
  - Emissions from all known sources distributed in time and space
  - An air quality forecast is no better than the emissions it uses!

- An air quality model
  - Combines meteorology with emissions, transporting and dispersing these emissions
  - Includes chemical reactions and physical processes

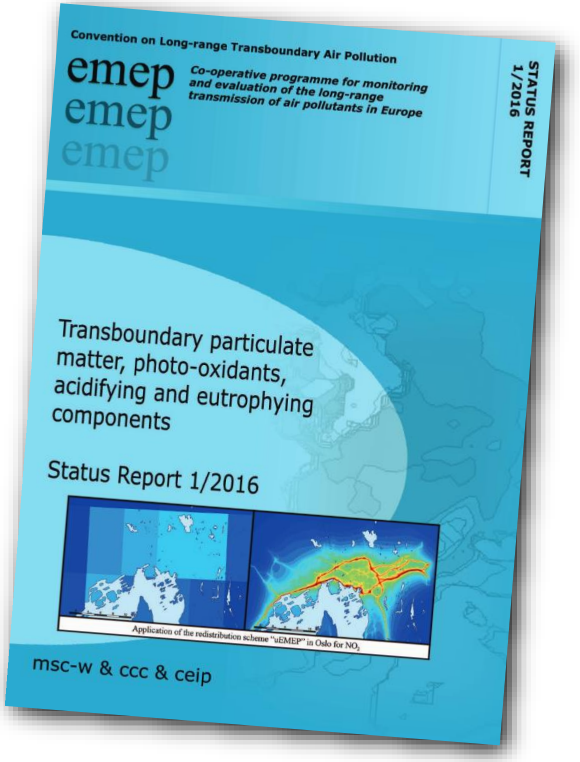
- Interpretation and communication

What is EMEP?

- **EMEP** stands for the **E**uropean **M**onitoring and **E**valuation **P**rogramme and is part of the United Nations **C**onvention on **L**ong-**R**ange **T**ransboundary **A**ir **P**ollution (CLRTAP)

- **'The EMEP model'** is the regional chemical transport model used within this Programme to calculate pollutants for all of Europe (15 km). It is now also used globally (40 km) and in Norway (2.5 km). It has been developed at MET Norway.

- **'uEMEP'** (=urban EMEP) is the fine resolution dispersion model that calculates concentrations on 'sub-grids' from 250 – 50 m in size within the EMEP model



http://emep.int/publ/reports/2016/EMEP_Status_Report_1_2016.pdf

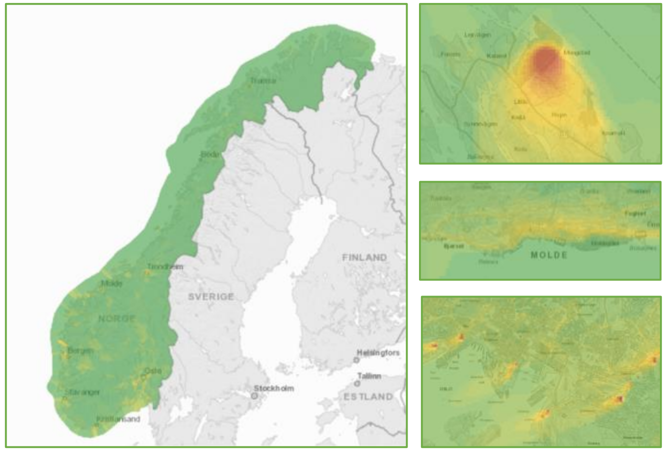
Description of the modelling system

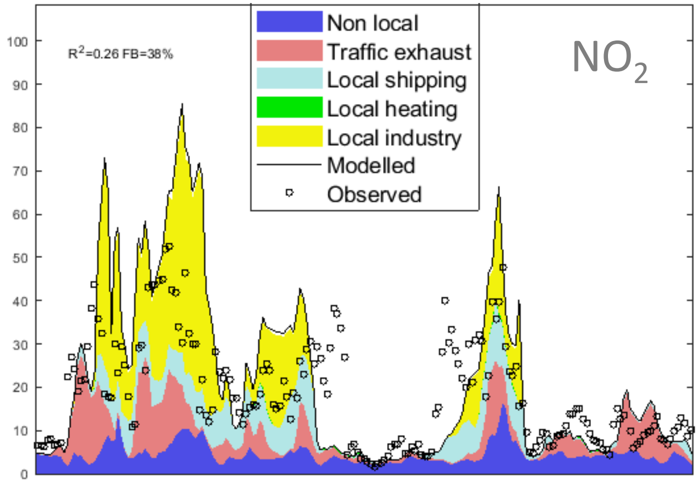
What does the forecasting system deliver?

- 2-day hourly ***forecasts*** for all of Norway at 250 – 50 m for the pollutants PM_{10}, $PM_{2.5}$, NO_2 and O_3

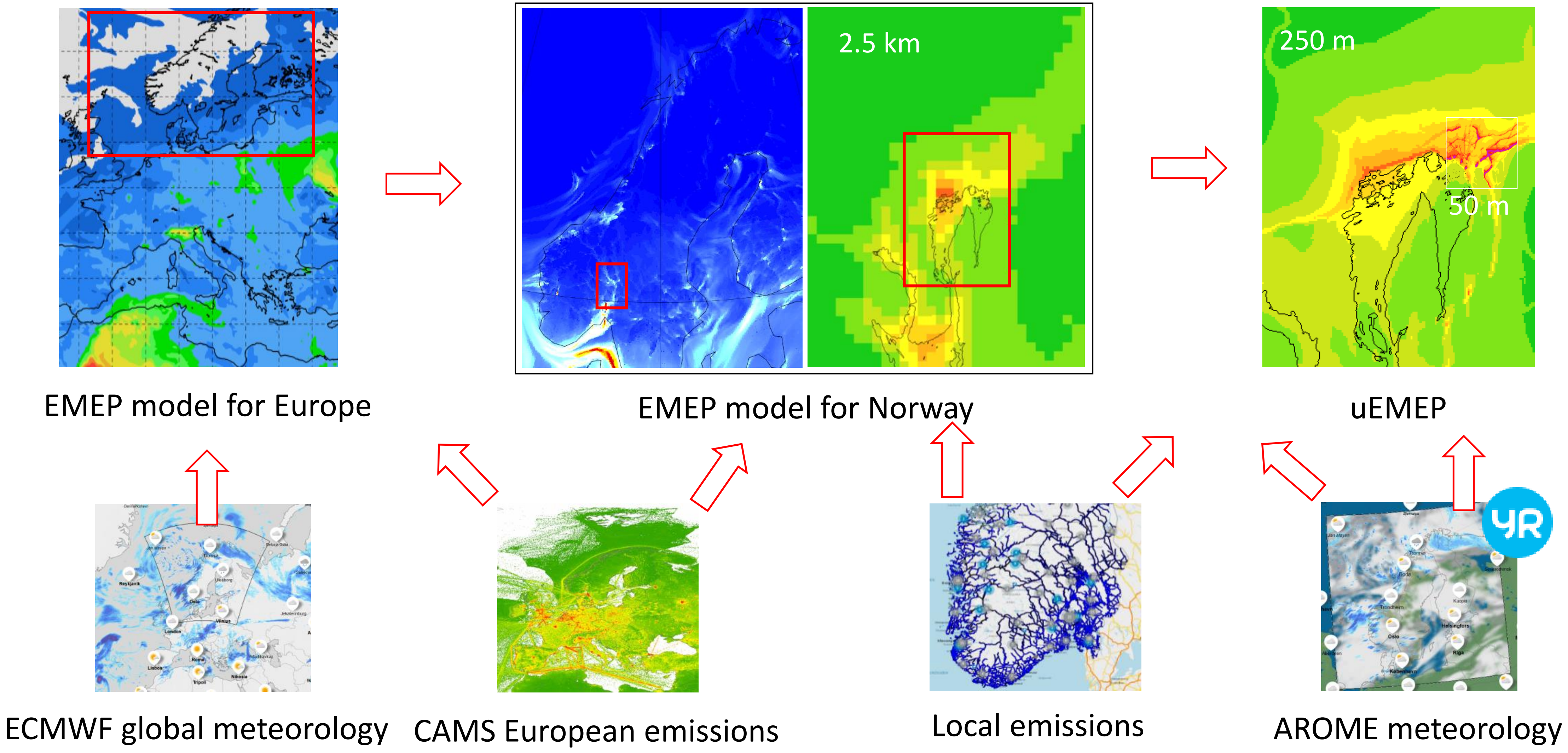
- Local ***source contribution*** for each pollutant:
  - Traffic exhaust
  - Traffic non-exhaust (mostly road dust)
  - Shipping emissions (exhaust only)
  - Industrial emissions
  - Residential wood combustion
  - Other sources (mostly non-local contributions)

- Both forecasts and measurements are presented daily to the public through a web interface



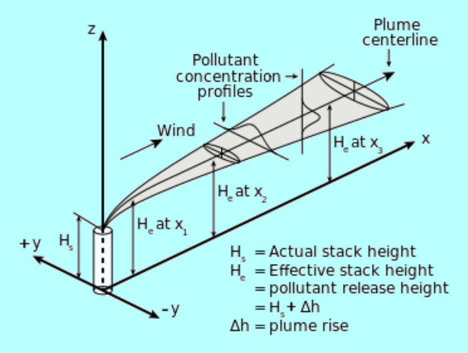


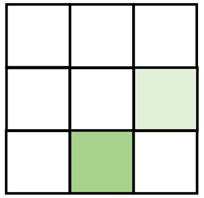
Overview of modelling in the forecast system

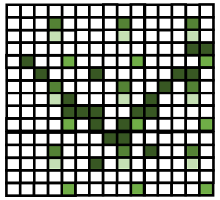


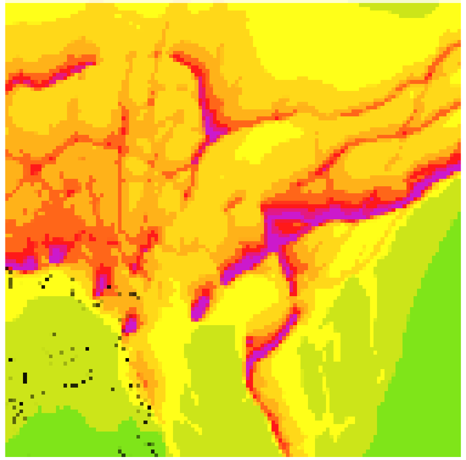
The uEMEP model

- uEMEP is based on Gaussian plume modelling
- It places emissions into **sub-grids** (grids much smaller than the EMEP grid) and calculates each sub-grid emission contribution to all other sub-grids within a 10 x 10 km^2 region
- Smallest sub-grids are 50 m and the largest are 250 m
- A chemistry scheme is used only for $NO_x/O_3/NO_2$
- uEMEP sub-grid concentrations are combined with EMEP grid concentrations in a special way to include local and non-local sources and avoid double counting

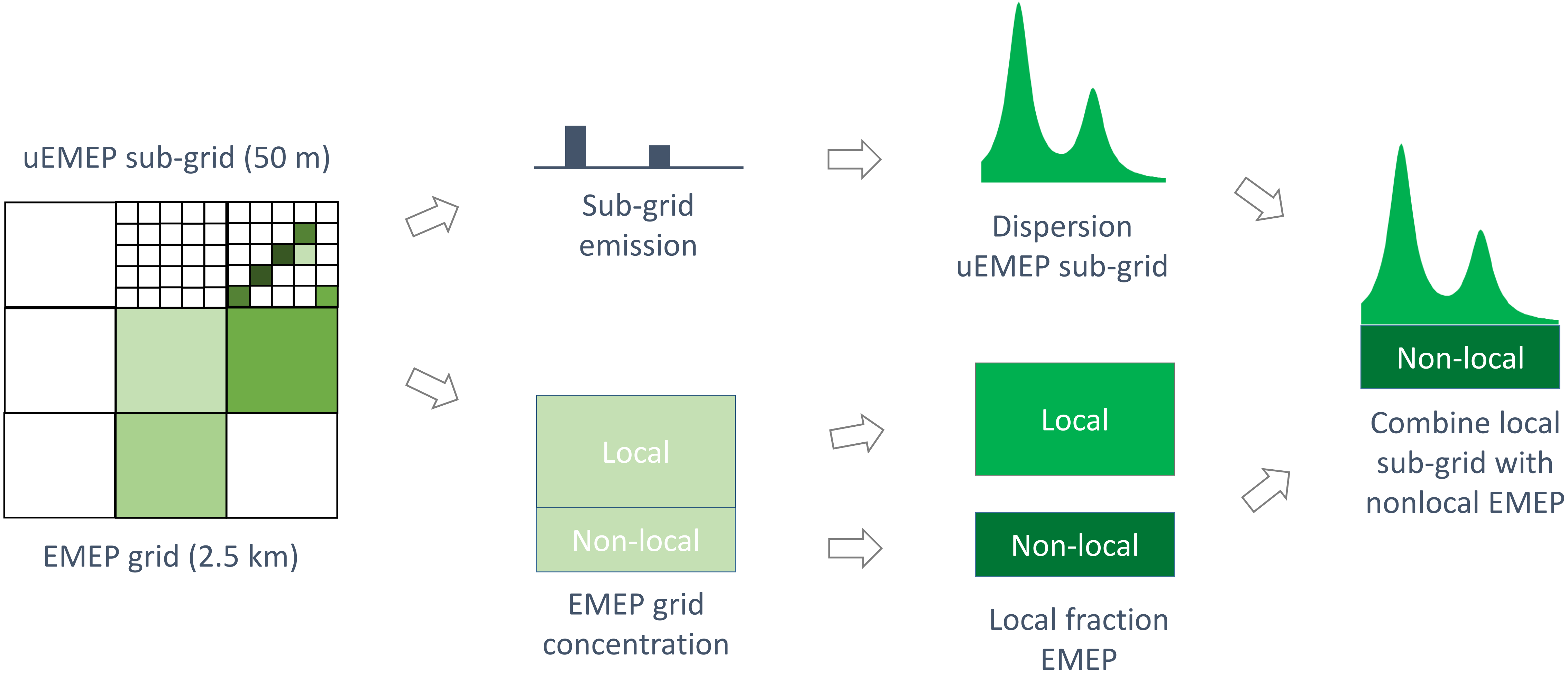








How uEMEP sub-grids are combined with EMEP grids



Emissions

Emissions in uEMEP

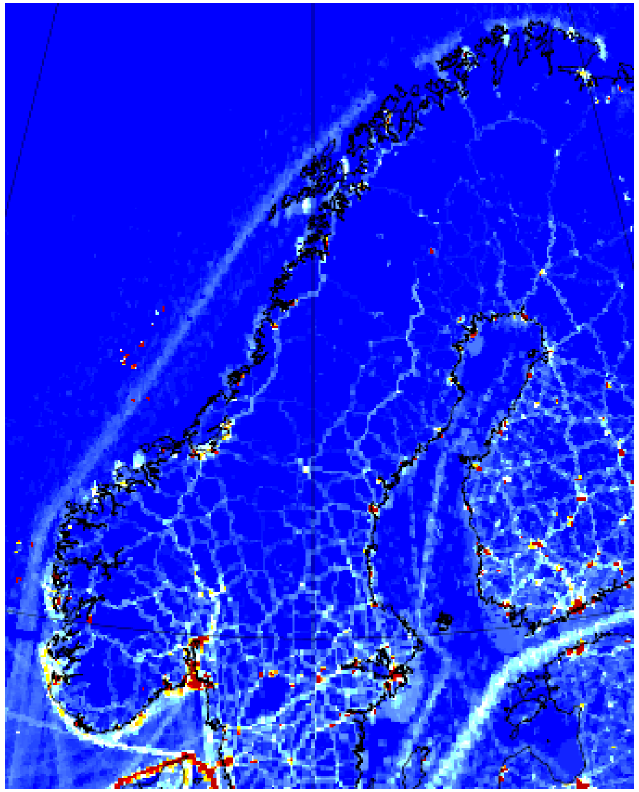
- uEMEP calculates the most important emissions sources in Norway for high resolution modelling. These are:
  - Traffic exhaust (per road segment)
  - Traffic non-exhaust (per road segment)
  - Shipping emissions (250 m grid)
  - Residential wood burning emissions (250 m)
  - Industrial emissions (per industry)
- All other source sector contributions are calculated on the larger scale using EMEP





Emission data used in the EMEP model

- EMEP uses emissions from all sectors based on the European emissions inventories developed by CAMS (Copernicus Atmosphere Monitoring Service *)
- These emissions are provided at 7 x 7 km^2 for all of Europe, including Norway
- High resolution emissions for Norway (50 – 250 m) are not the same as the CAMS European emissions
- CAMS emissions are replaced in the EMEP calculations with the high resolution emissions for Norway after aggregation to 2.5 km
- The same high resolution emissions are then used in both the EMEP and uEMEP calculations



NOx emissions used in EMEP

* https://atmosphere.copernicus.eu/

Some limitations

- uEMEP does not include buildings or other obstacles
- Meteorology is based on 2.5 km grids so details within these grids, e.g. due to variation in terrain, obstacles, are not represented
- Some emissions lack details, e.g. for industry stack heights and information for plume rise calculations are not available
- There are some significant uncertainties in the traffic data
- The uEMEP calculation region is limitted to 10 x 10 km^2 (4 x 4 EMEP grids). For some industrial sources with large plumes this is not large enough

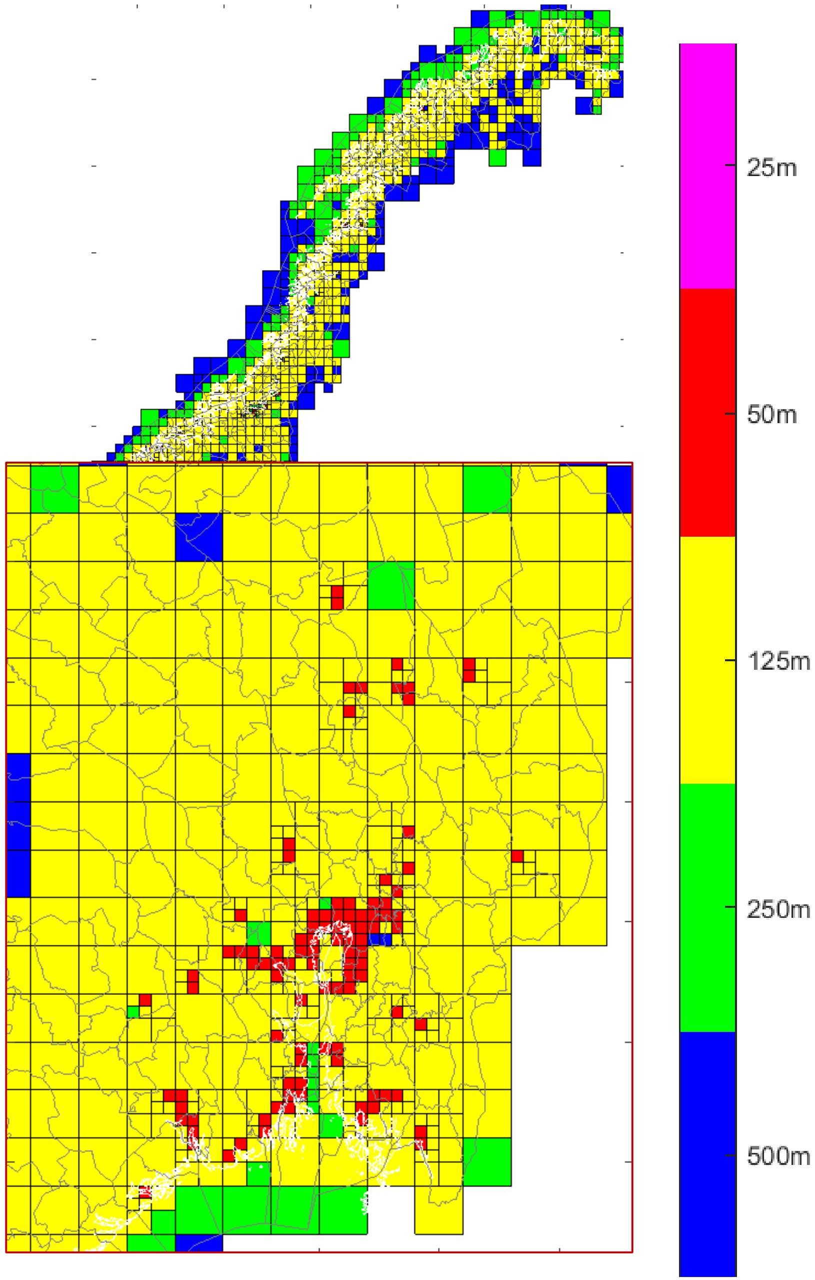
Model implementation

Model implementation: pollutants and sources

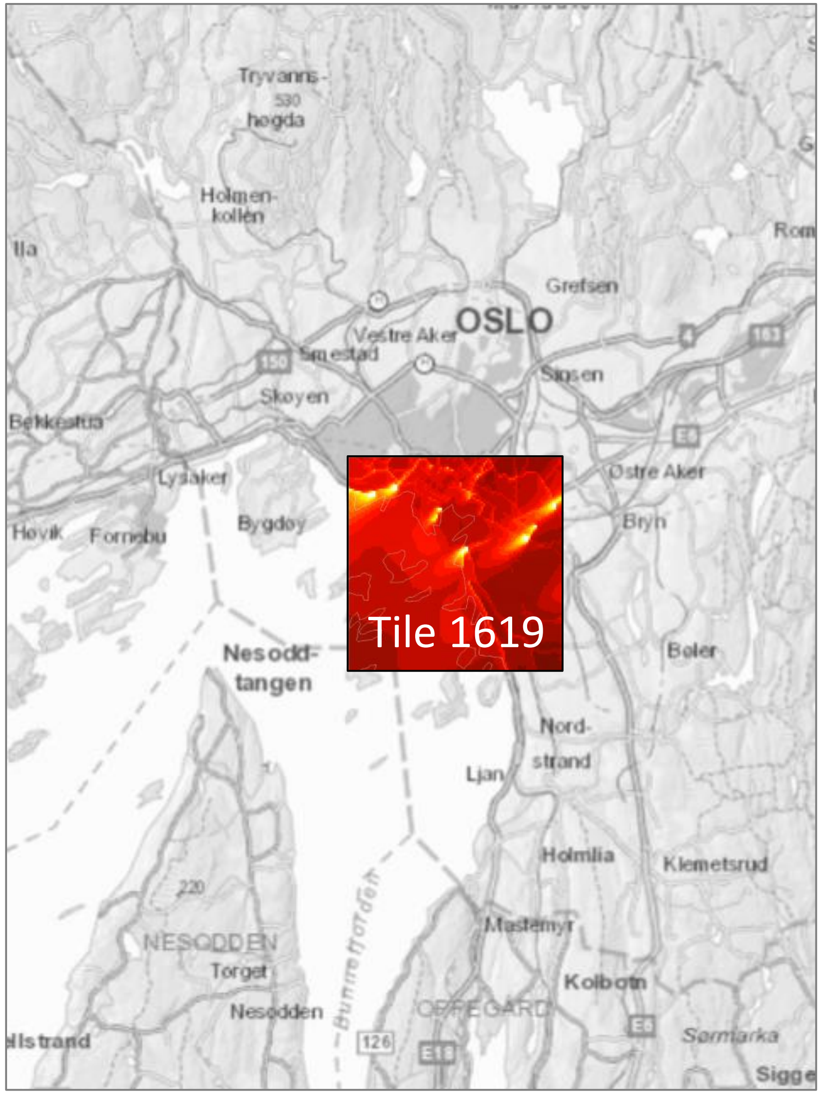
- uEMEP calculates the following pollutants
  - NO_x, NO_2, O_3, PM_{10} and $PM_{2.5}$
- For each of these pollutants the fractional contribution of each source is calculated and provided
  - Traffic exhaust
  - Traffic non-exhaust (road dust)
  - Shipping
  - Residential wood burning
  - Industry
  - Non-local contribution (> 5 km)

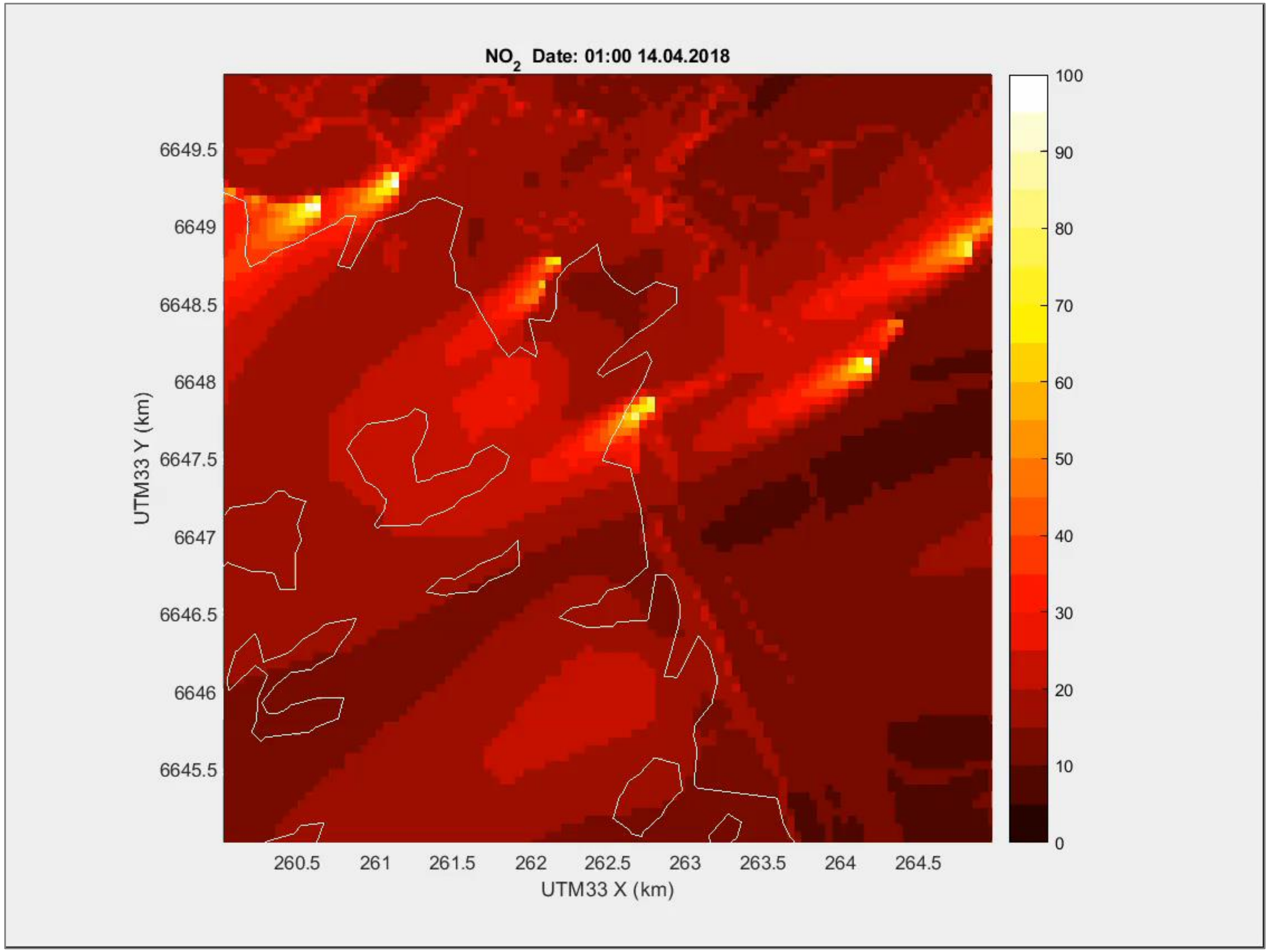
Model implementation: tiling

- It is not possible, or necessary, to calculate concentrations at 50 m resolution for all of Norway
- uEMEP covers the entire country at a range of resolutions and uses tiling to achieve this
- 1864 separate tiles are used ranging in size from 40 x 40 km^2 to 5 x 5 km^2
- Grid resolution is highest (50 m) in urban areas within the 5 x 5 km^2 tiles



Example calculation : Tile 1619, 5 x 5 km^2, 50 m resolution





Forecast maps

Direct link to web site

luftkvalitet.miljostatus.no

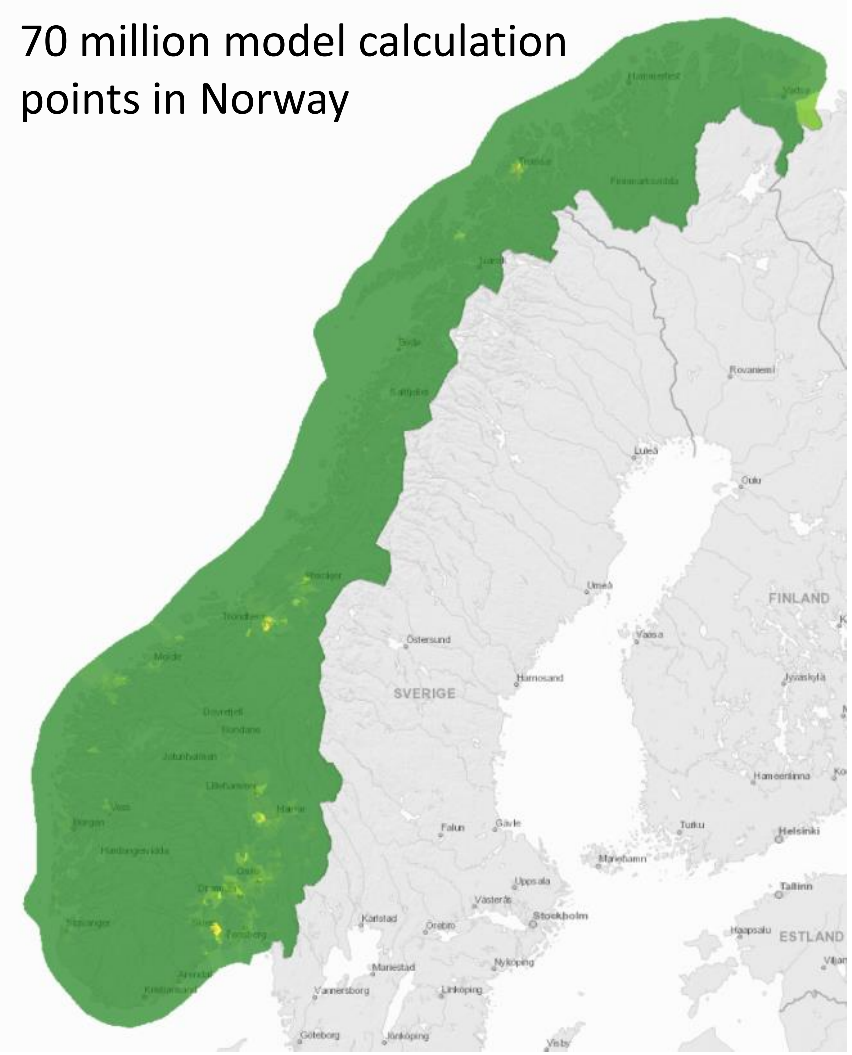
Direct link to maps

luftkvalitet.miljostatus.no/kart/59/10/5/aqi

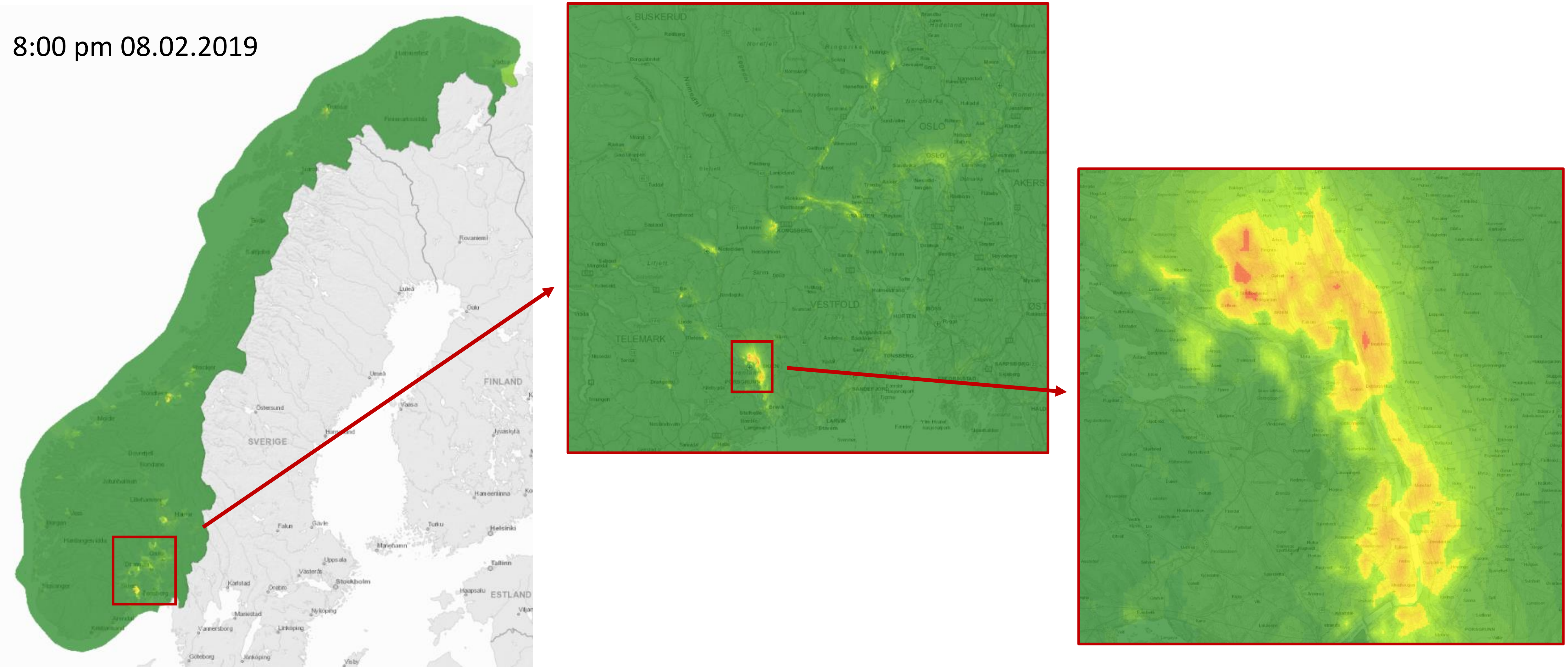
Model region and measurements:

72 measurement stations in Norway

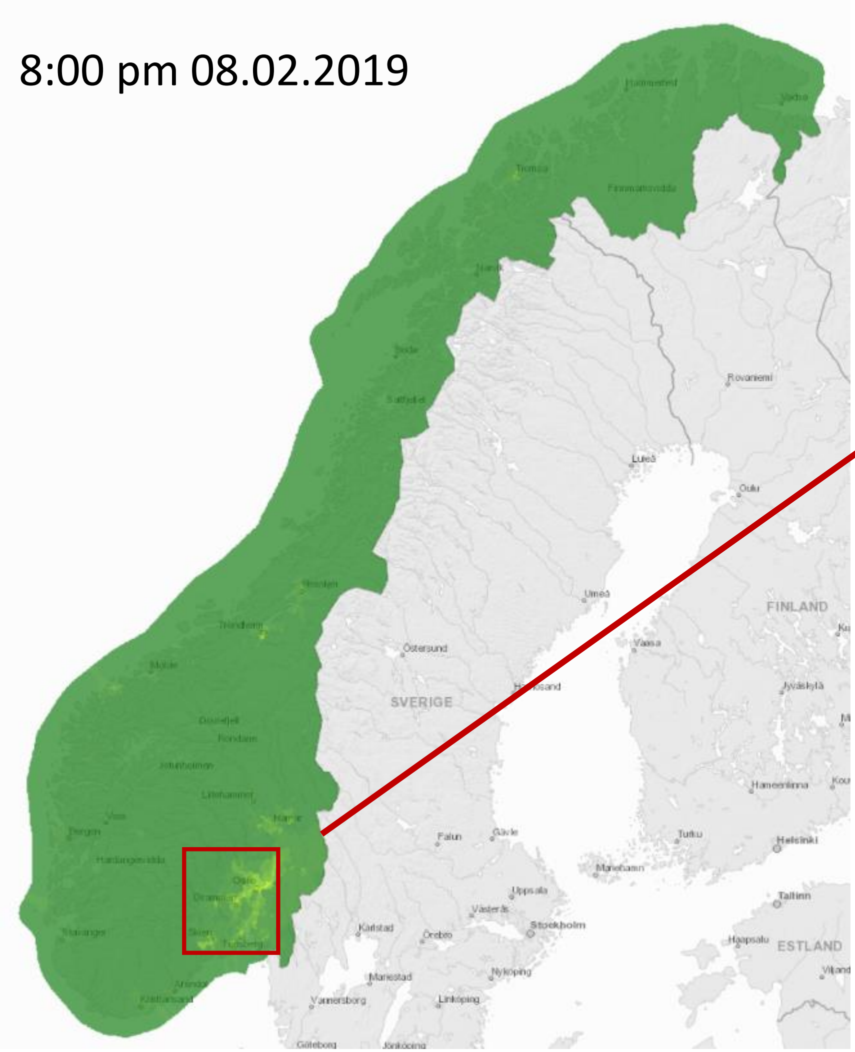
70 million model calculation points in Norway

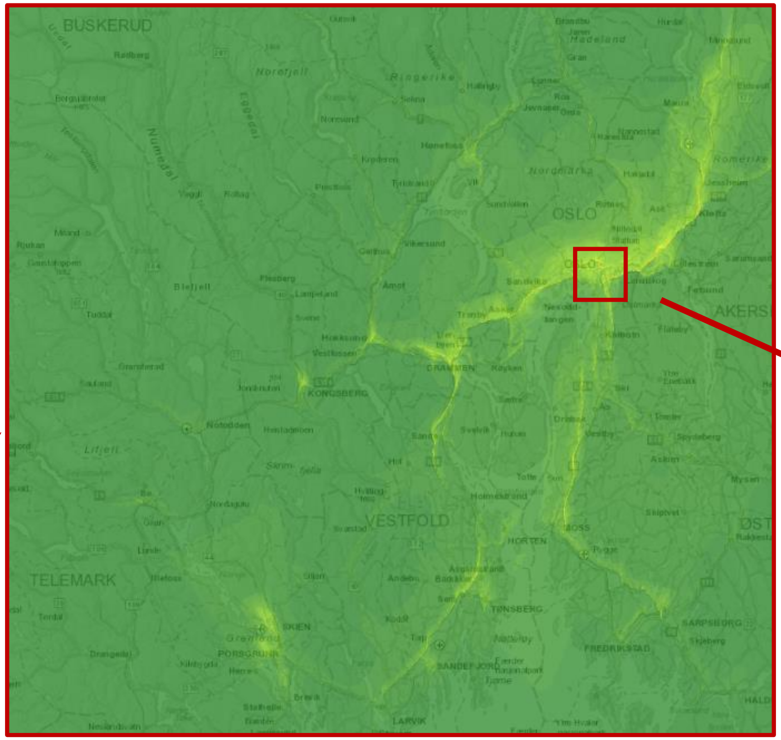


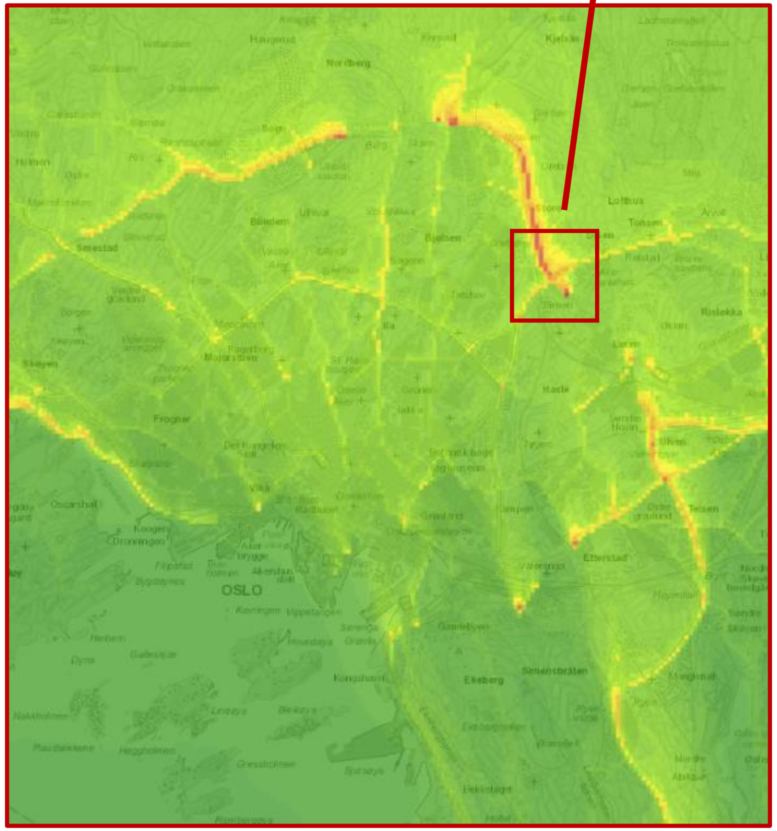
Forecast maps $PM_{2.5}$: mostly from wood burning



Forecast maps NO_2: mostly from traffic





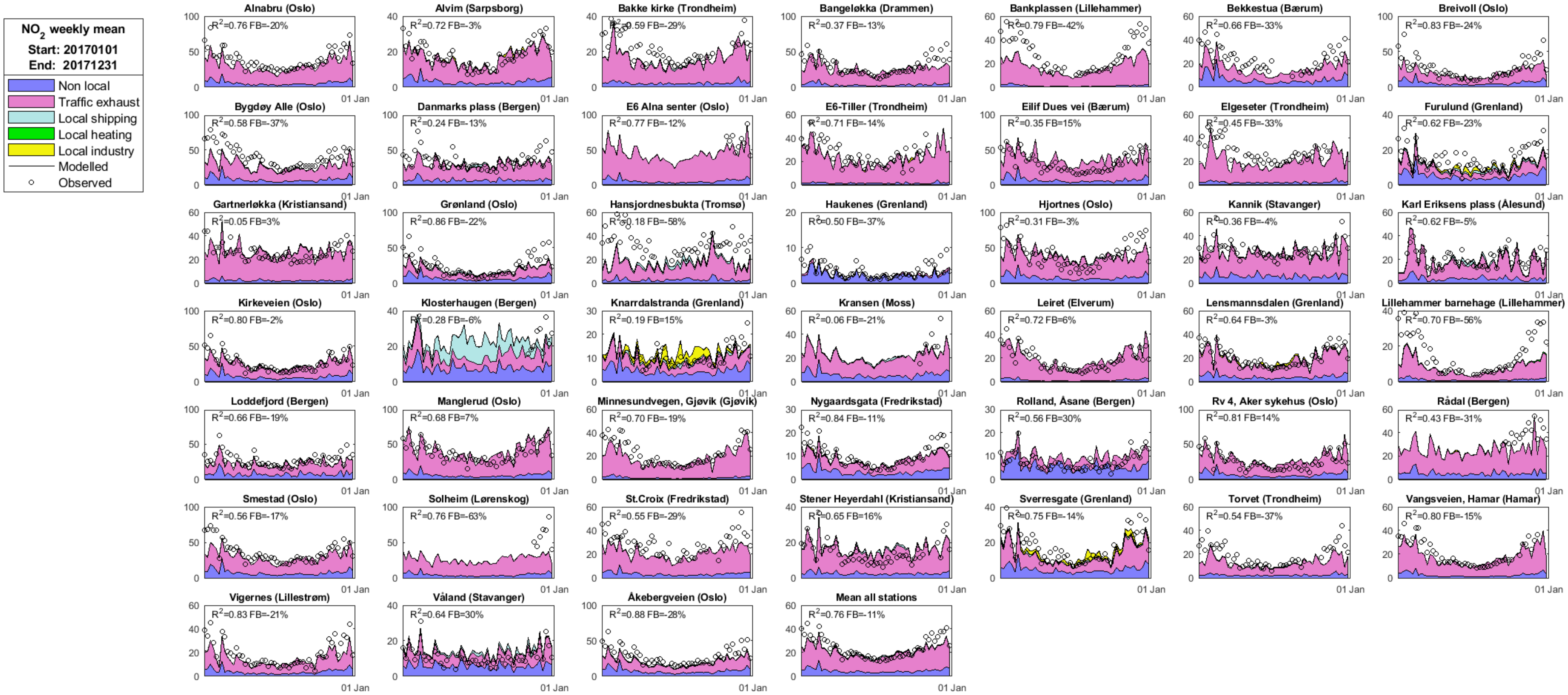


Comparison with measurements for 2017

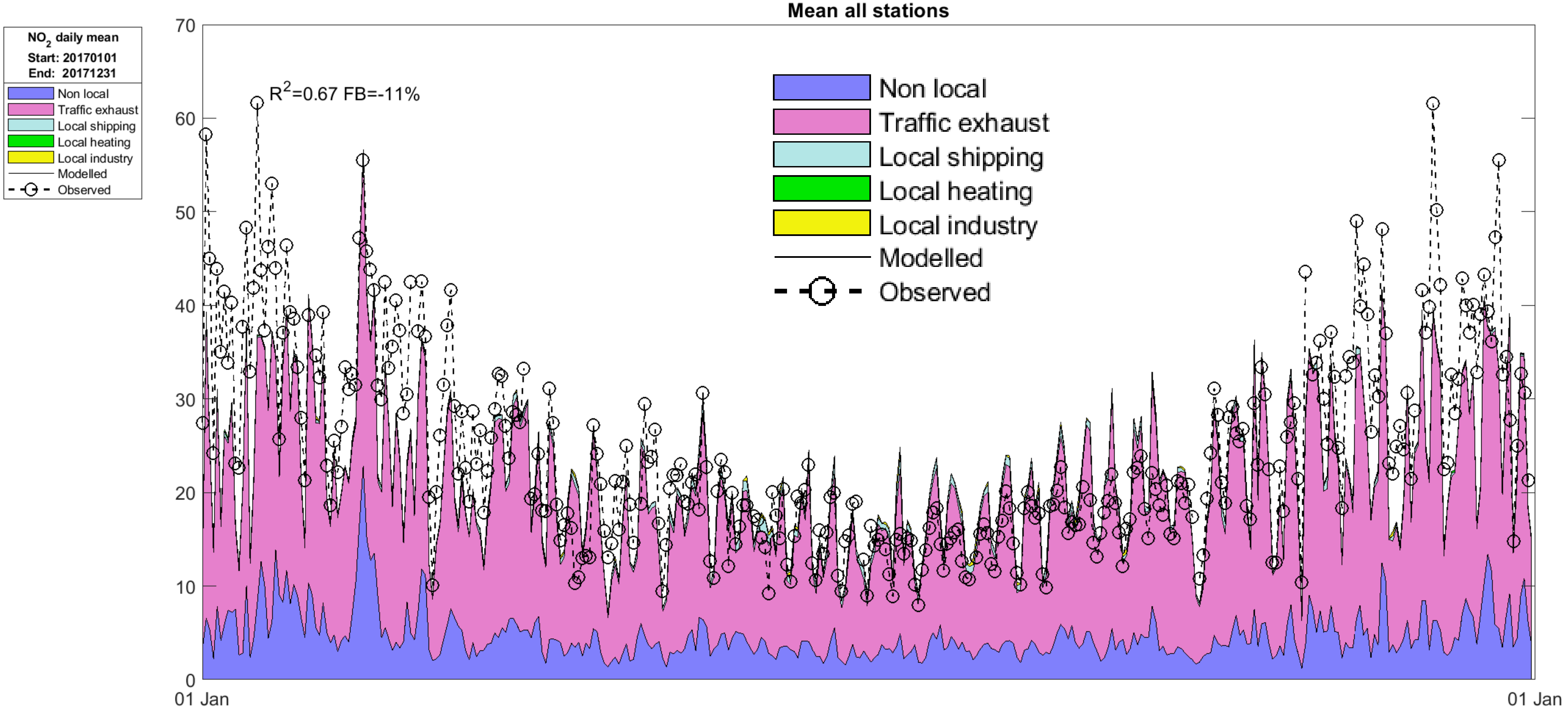
Overview

- The concentrations from 2017 have been calculated at all measurement sites for validation
- The calculations are made every day, and the first day of the forecast is used
- Pollutants shown are PM_{10}, $PM_{2.5}$ and NO_2
- Timeseries and scatter plots are shown

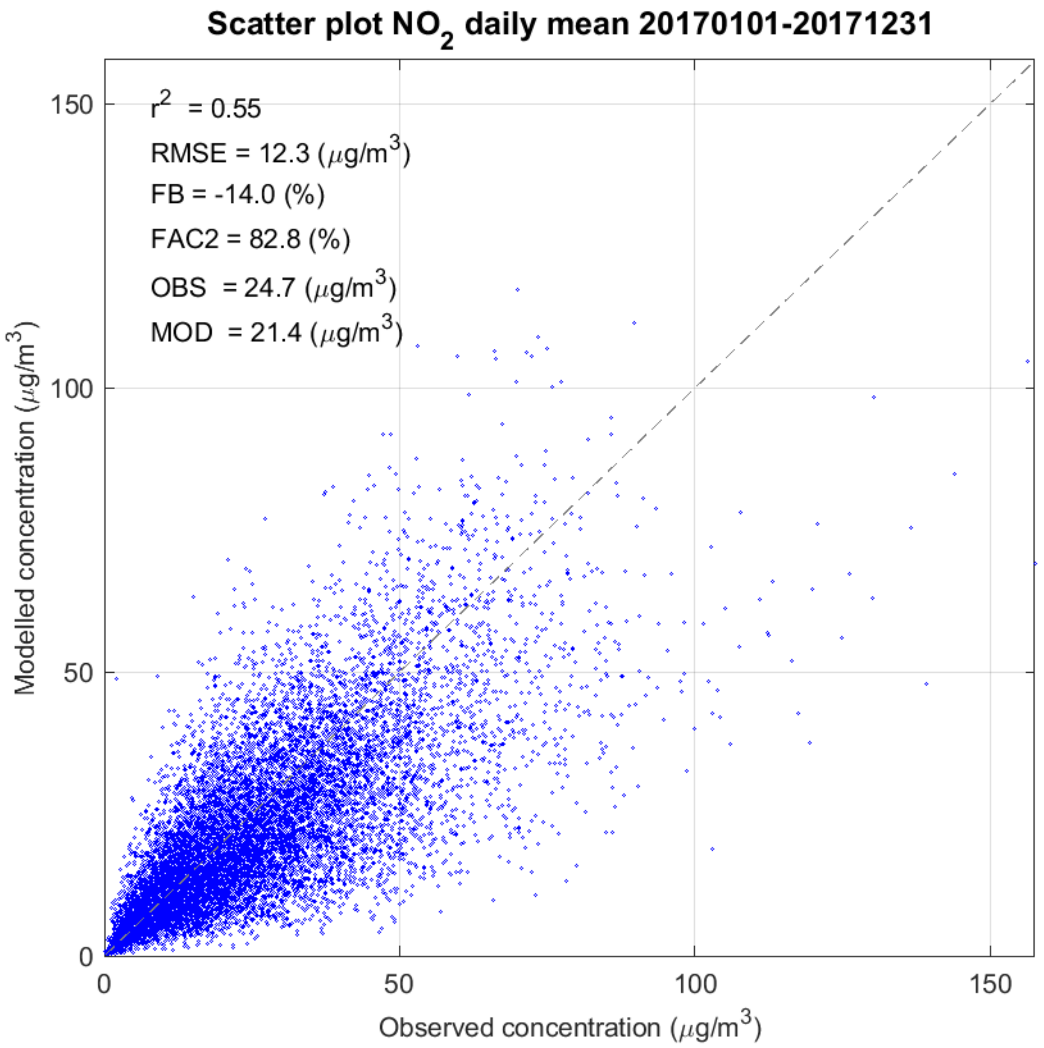
Forecast validation NO_2 2017:
all stations, weekly means

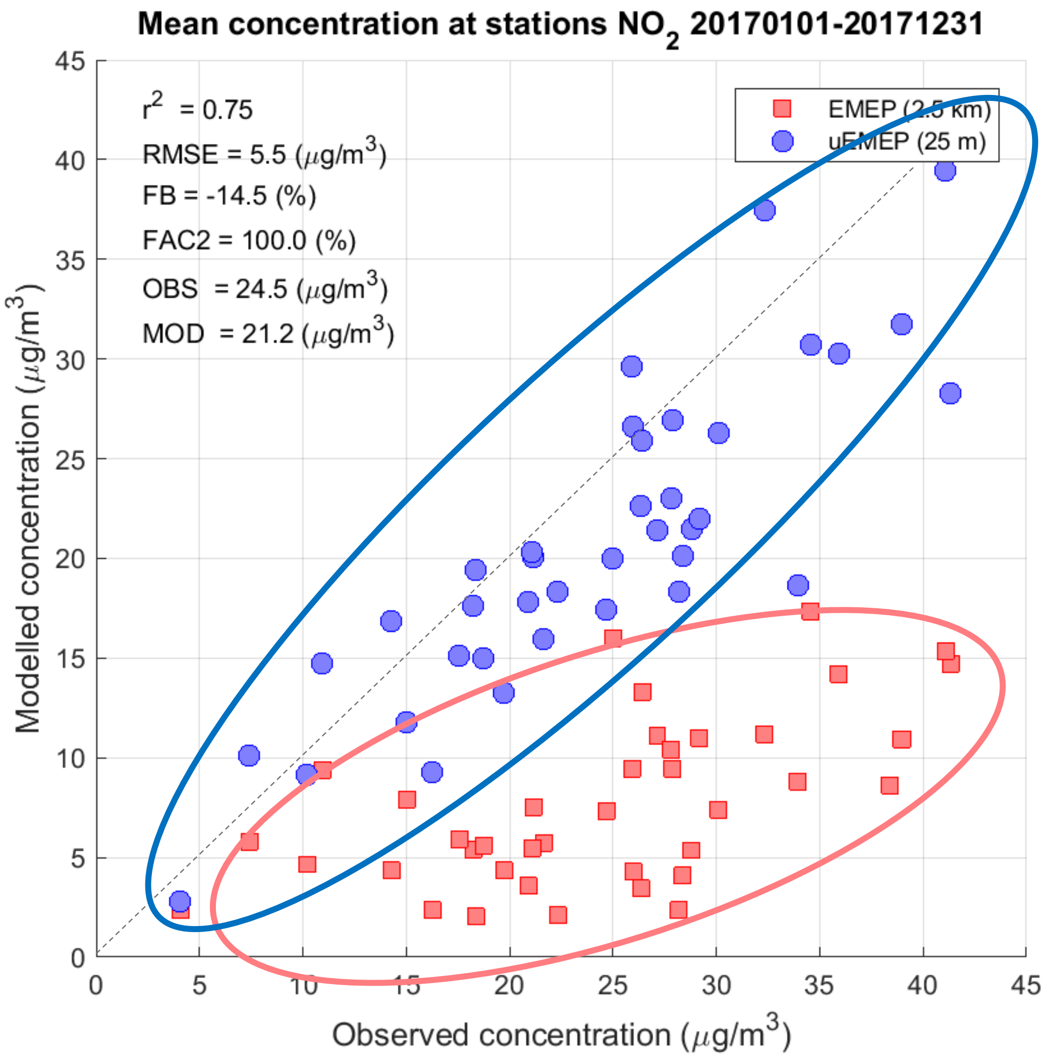


Forecast validation NO_2 2017:
mean all stations, daily mean time series

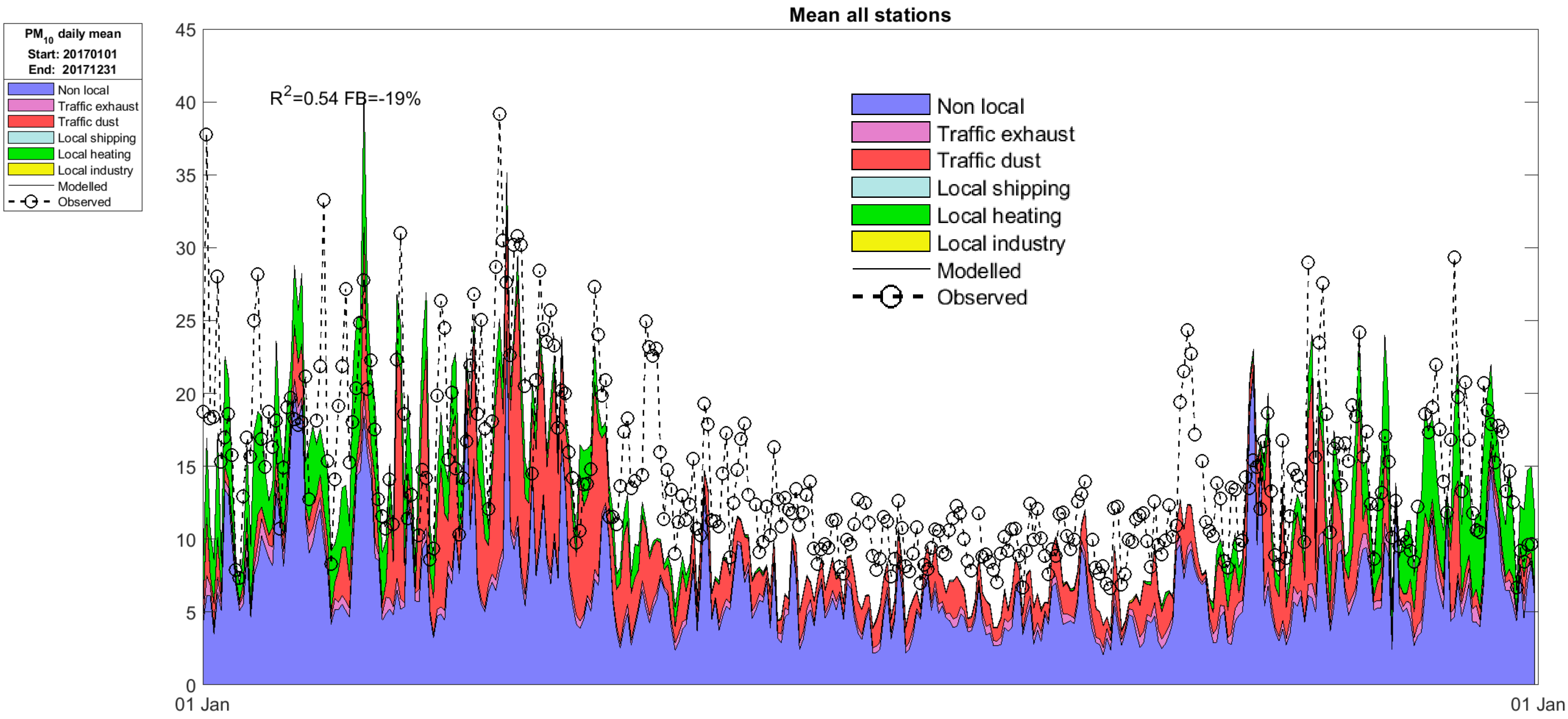


Forecast validation NO_2 2017:
daily and annual mean scatter plots

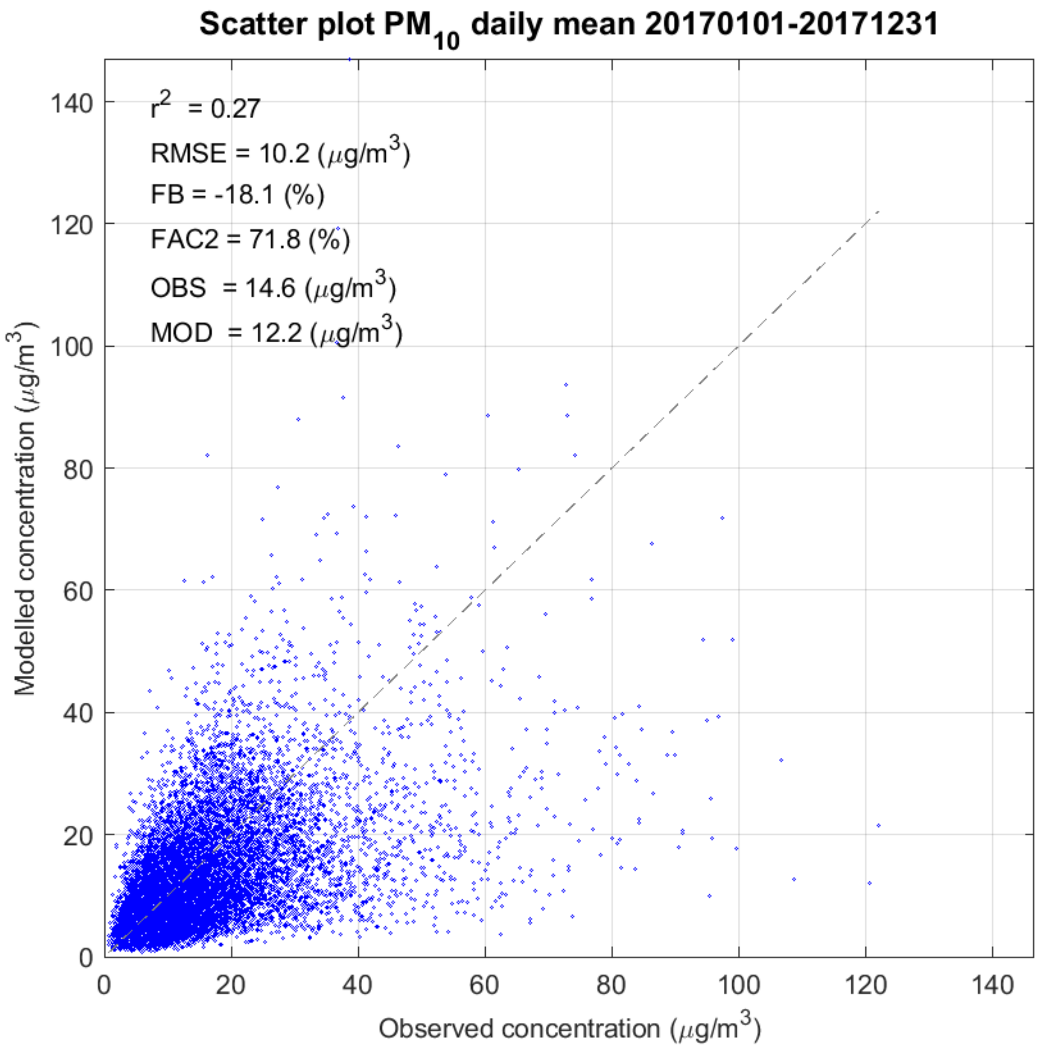


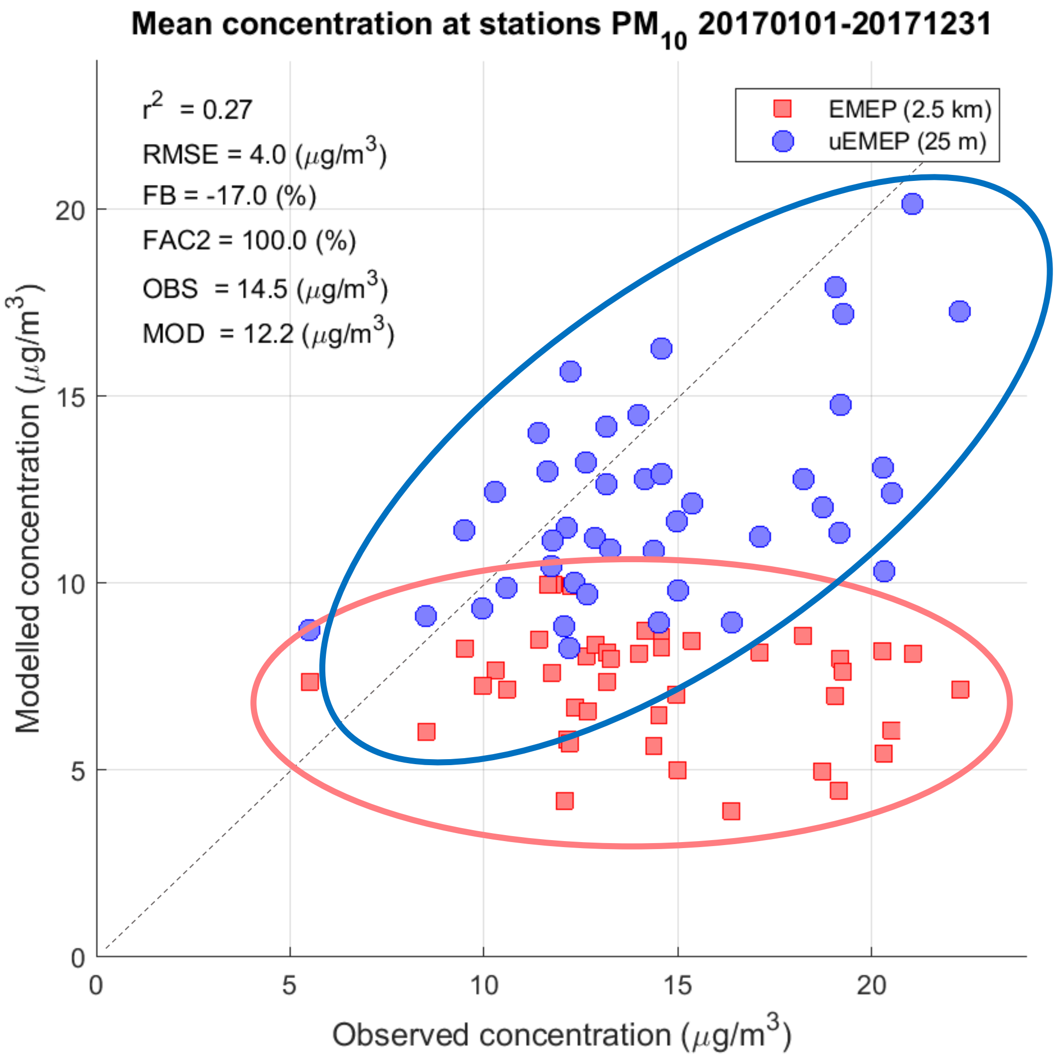


Forecast validation PM_{10} 2017:
mean all stations, daily mean time series

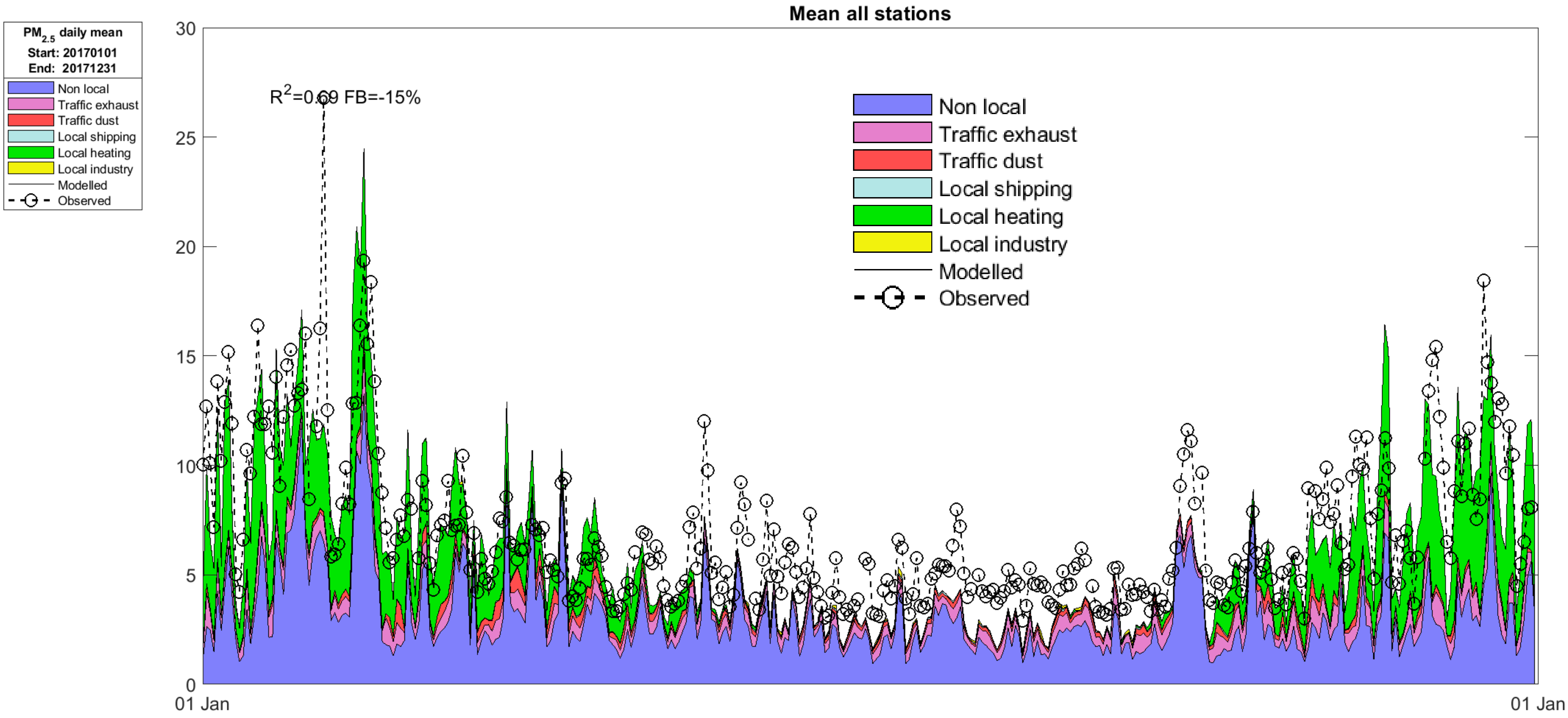


Forecast validation PM_{10} 2017:
daily and annual mean scatter plots

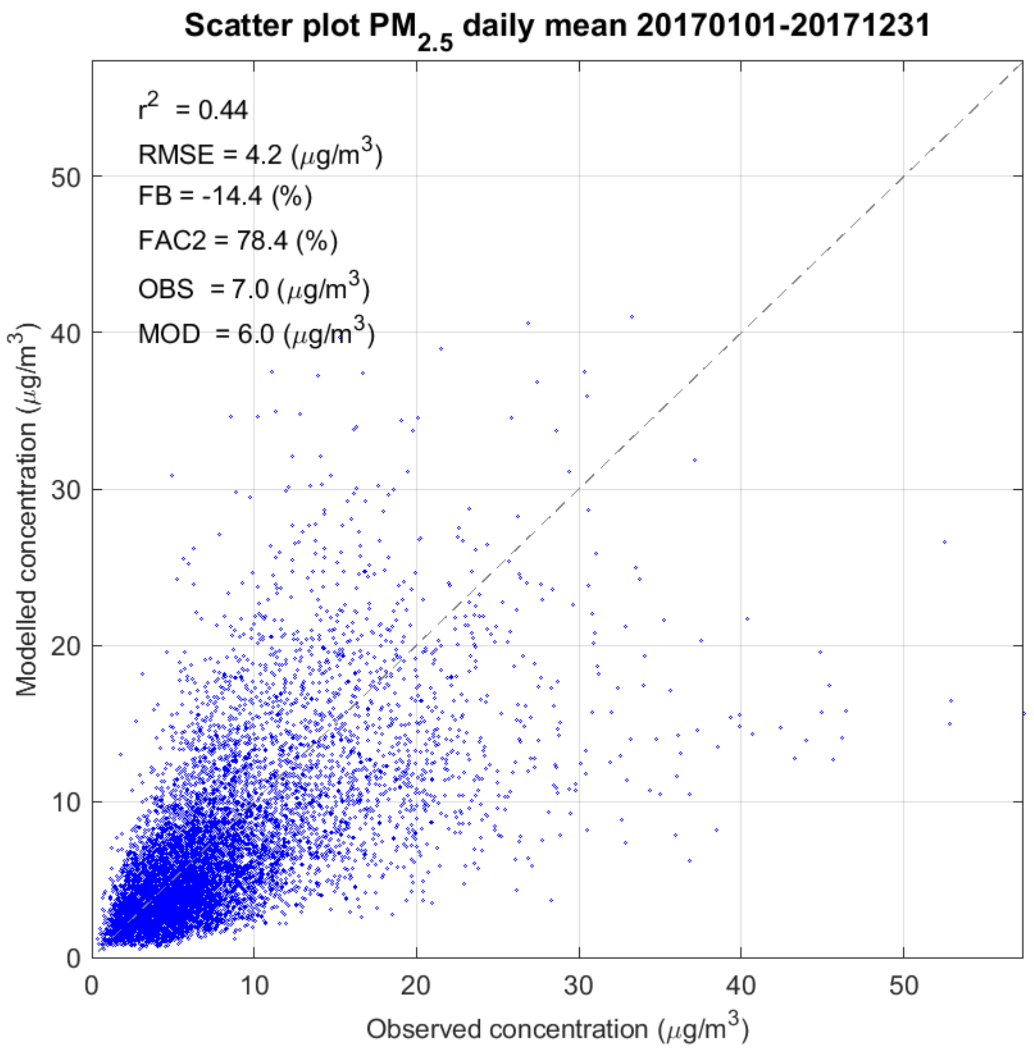


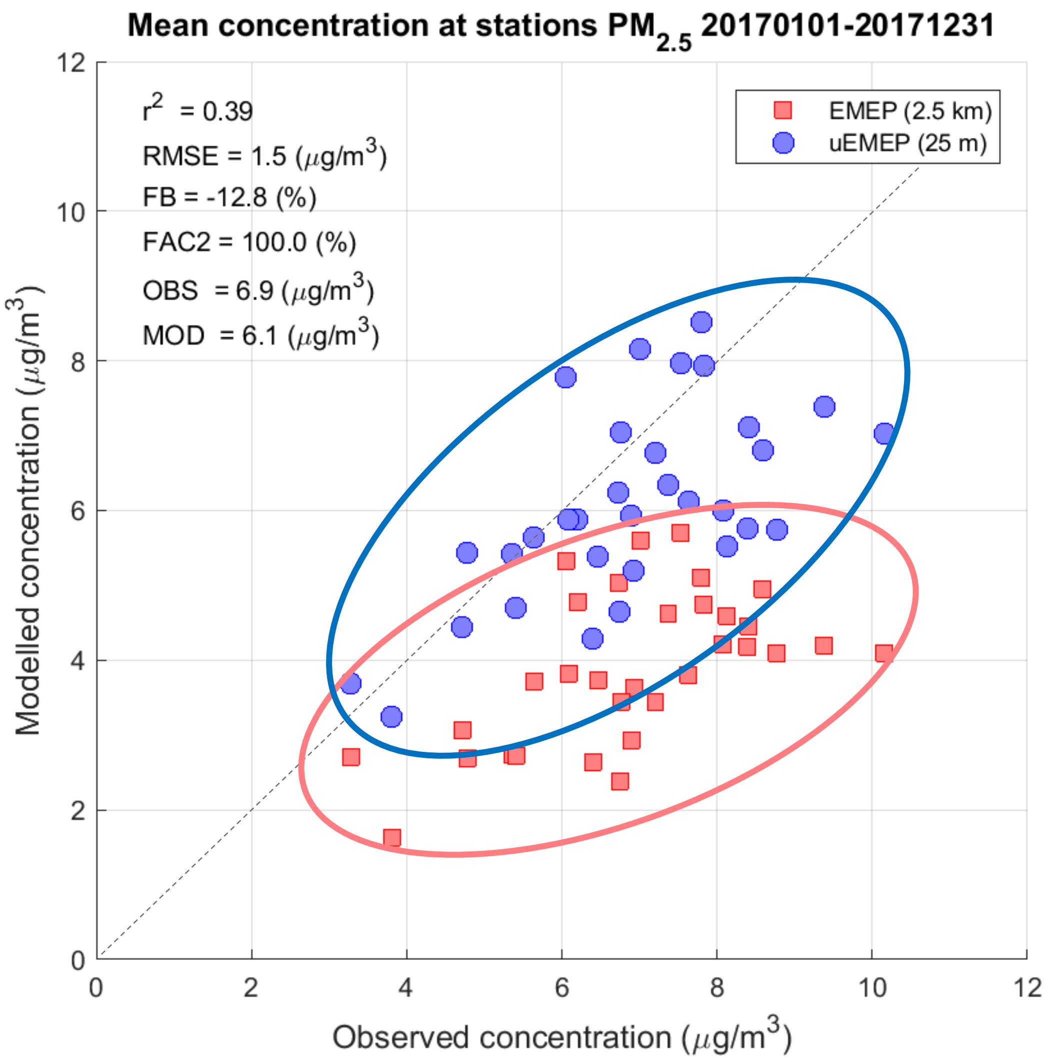


Forecast validation $PM_{2.5}$ 2017: mean all stations, daily mean



Forecast validation $PM_{2.5}$ 2017: daily and annual means





Main conclusions from the comparison

- High resolution modelling is necessary to properly capture the spatial variation seen in both NO_2 and PM measurements

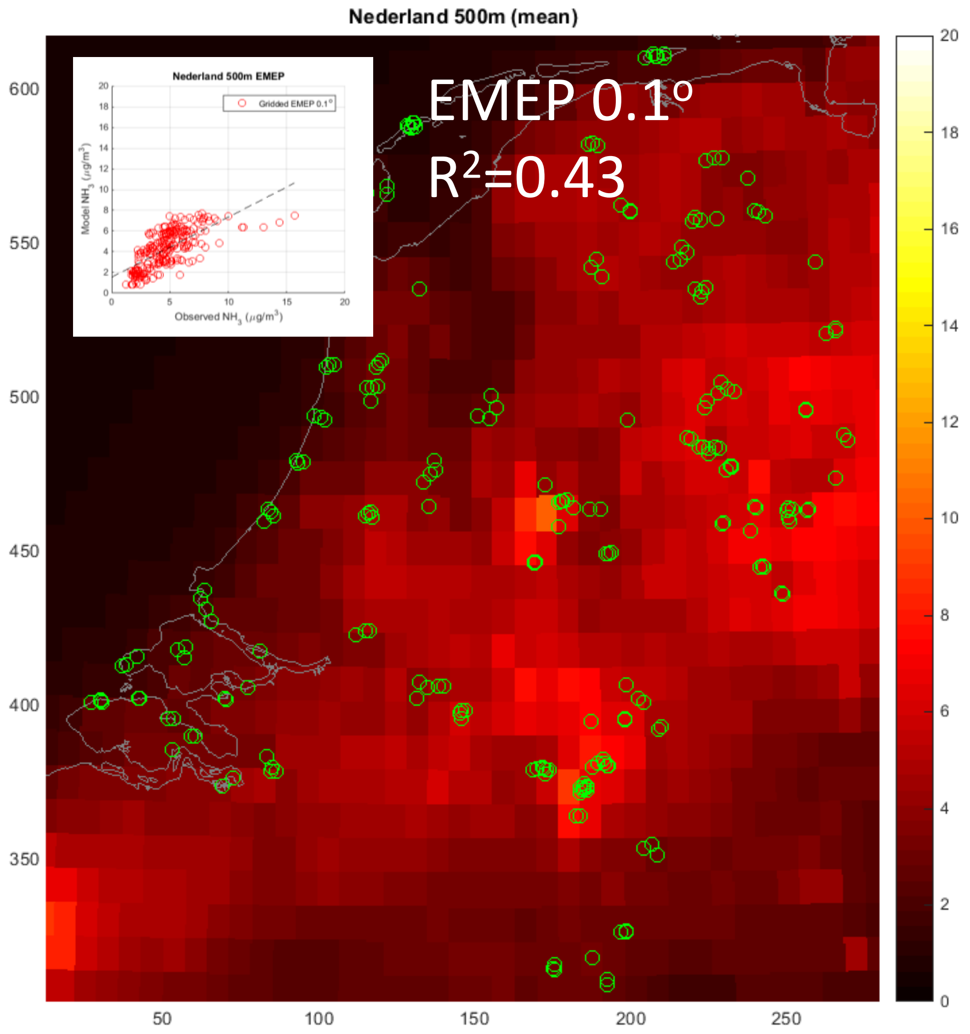
- NO_2 has the most spatial variability since the major source is local traffic
- NO_2 is very well modelled spatially, with some outliers, but is generally underestimated in the winter

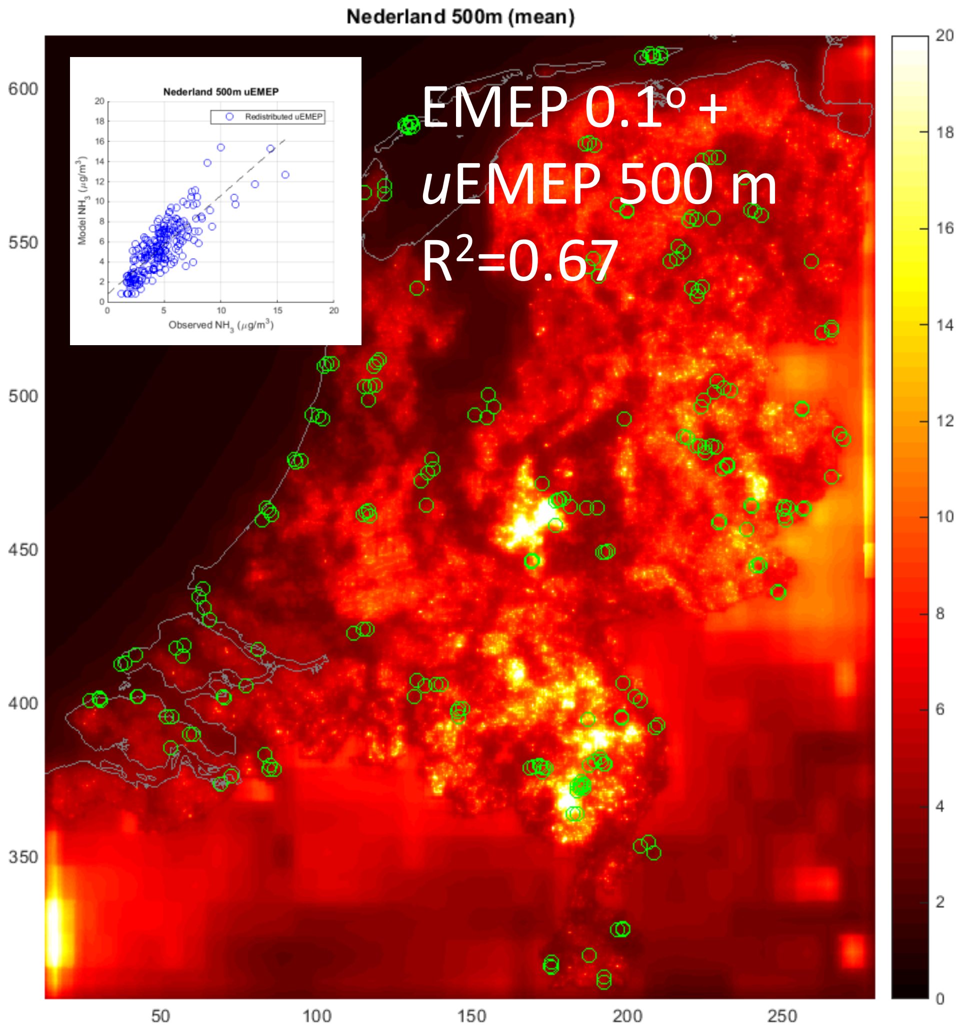
- $PM_{2.5}$ has the least variability since a significant part is from long-range transport
- PM_{10} from road dust (studded tyres) is well represented in the model
- $PM_{2.5}$ from wood burning is well represented in the model
- PM_{10} and $PM_{2.5}$ are both underestimated in the summer

Applications outside of Norway

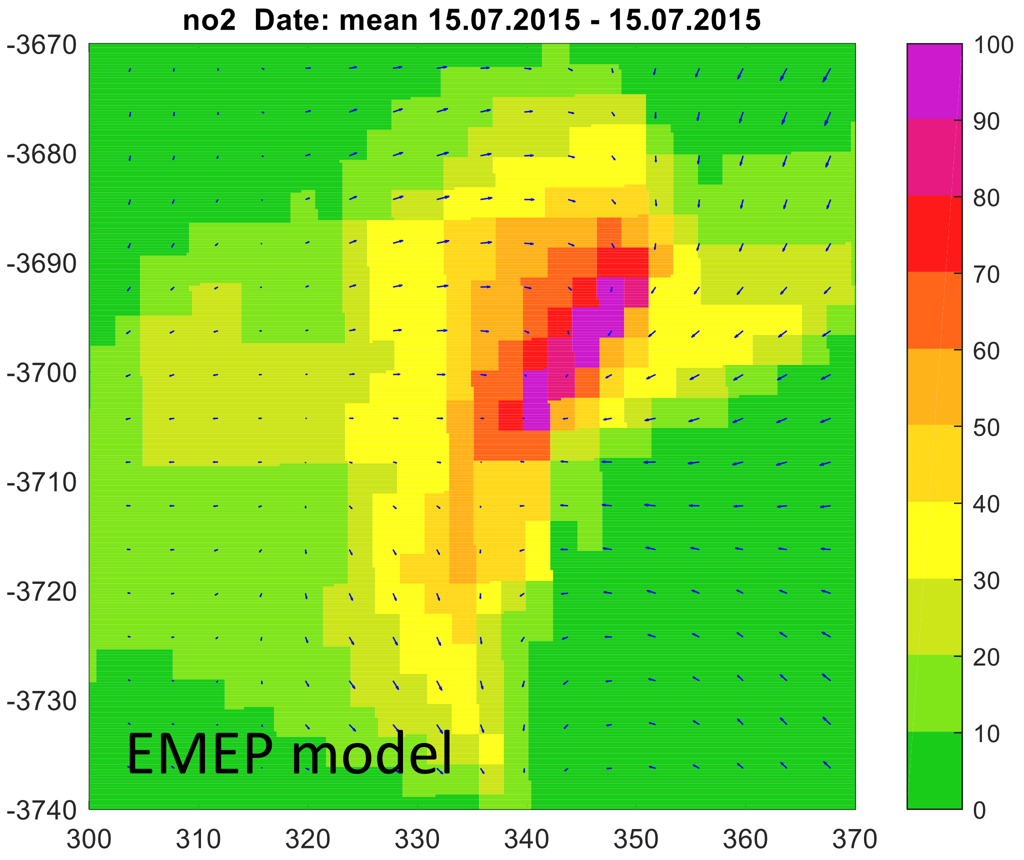
Test calculations for ammonia:

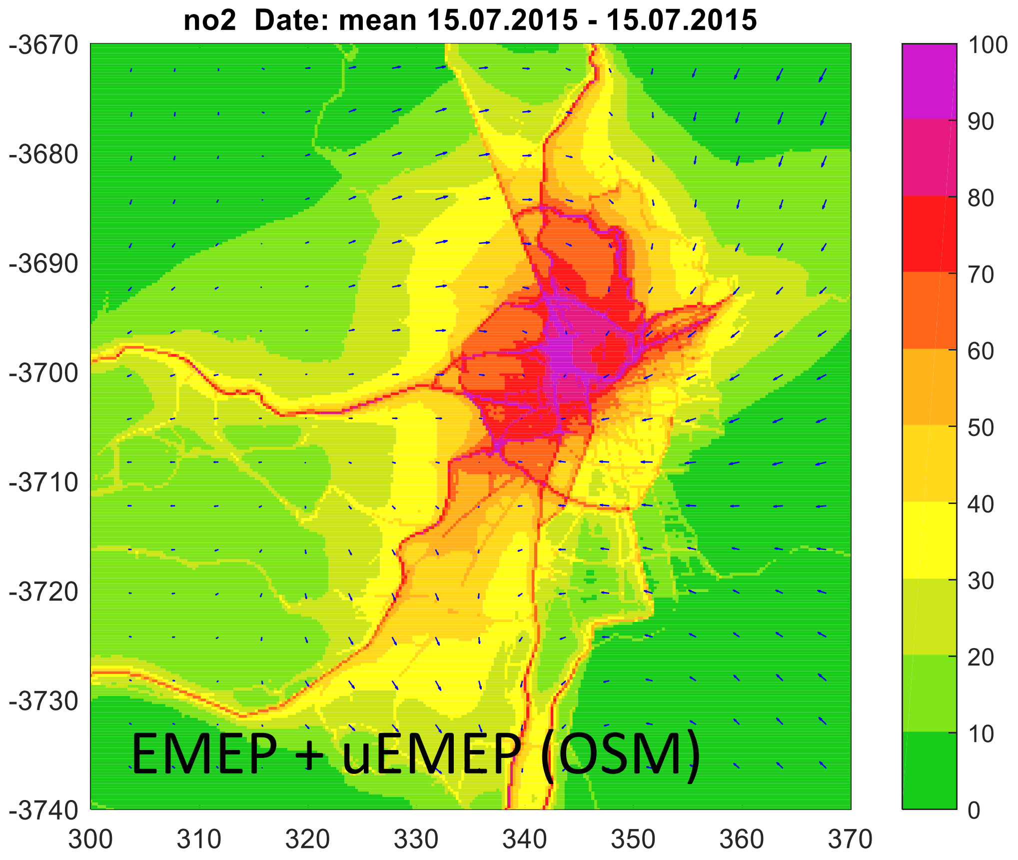
The Netherlands, annual mean (2015)



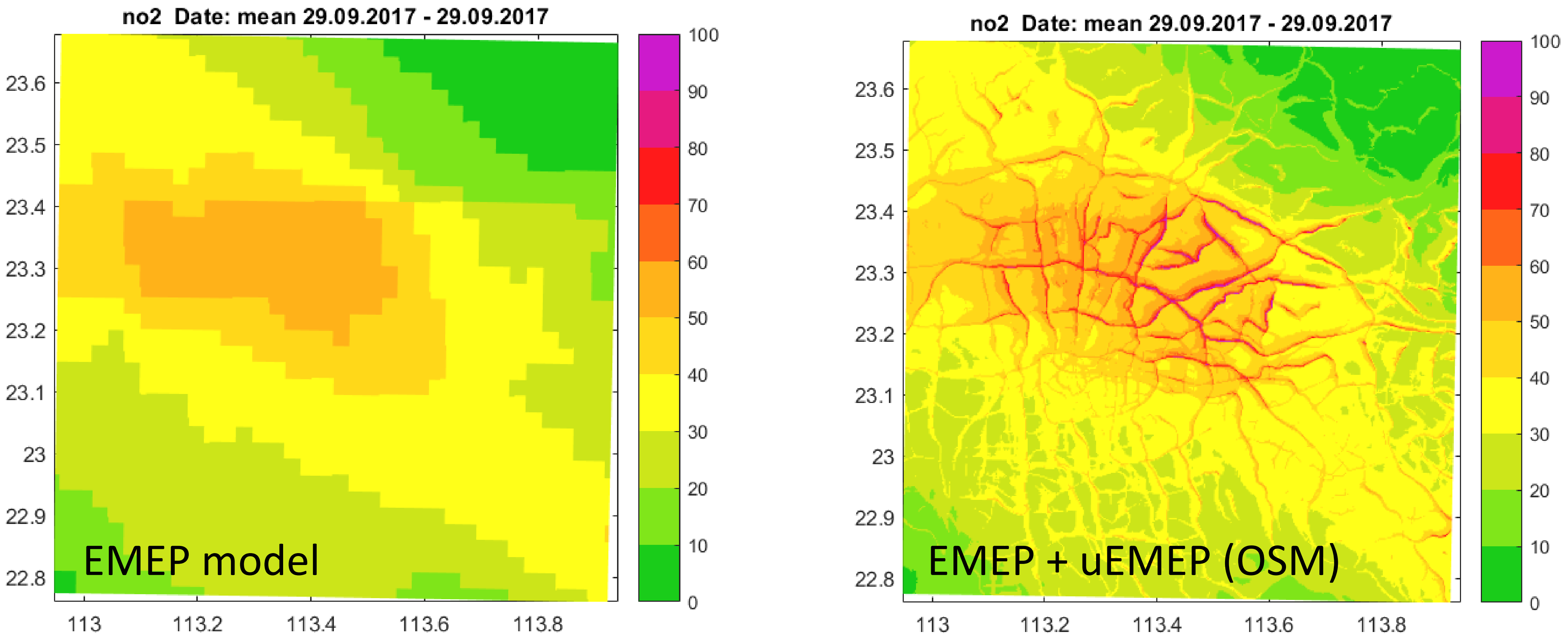


Test calculations NO_2 using Open Street Maps data
Santiago, Chile (15.07.2015)





Test calculations NO_2 using Open Street Maps data
Guangzhou, China (29.09.2017)



Summary

- uEMEP extends the modelling capabilities of the EMEP model from global scales down to very local scales
- It is now implemented in Norway for air quality forecasting and verified against all available measurement data
- The comparison with measurements is good but not perfect, in Norway we lack full knowledge of emissions
- It can be implemented in other regions as well but it does require a high level of detail in emission and/or proxy emission data
- Development will continue and application regions will be extended

Thank you for your attention

感谢您的关注

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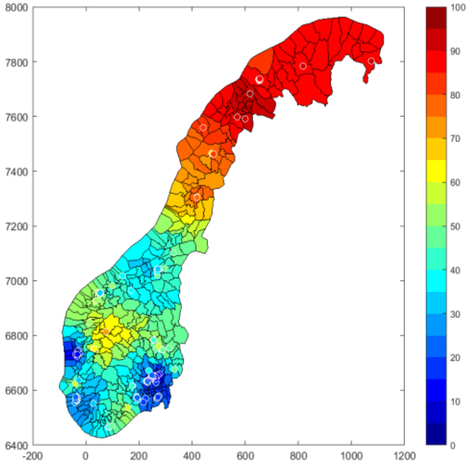
Additional slides

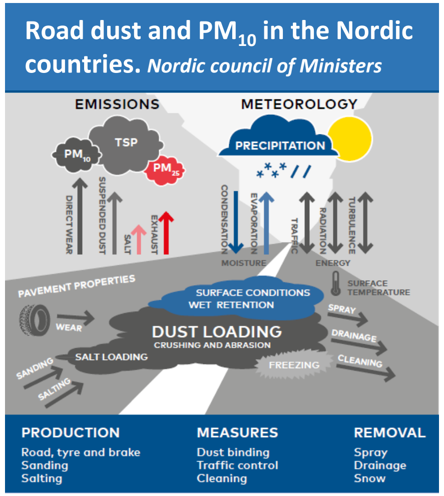
Traffic data and emissions

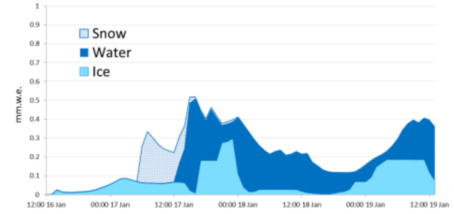
- Road traffic and road network data is taken from the road authorities database for state roads and from a traffic model for municipal roads
- In all 720 000 road segments are used containing 8 million individual road links
- NO_x emission factors are set everywhere to the national average, based on total road traffic emissions for Norway (SSB)
- One single time profile for all traffic is currently used
- The NORTRIP model is used for all roads to calculate road dust emissions (significant in Norway due to studded tyre use)
- Studded tyre share is derived from ~ 200 counting sites across the country (SVV) and distributed to each municipality
- Most emissions within tunnels exit at tunnel portals but some are deposited within the tunnels



Road dust emissions

- PM emissions from road, tyre and brake wear, as well as road salt, are calculated using the NORTRIP road dust emission model
- Calculates the road surface conditions and the accumulation of wear particles on the road surface
- Calculates the direct emission from studded tyres and the suspension of the road dust particles
- Salting and dust binding are included in the model but these activities are unknown. Salting activities are estimated based on a set of salting rules and snow ploughing automatically occurs above a snow depth threshold
- No information on dust binding activities is available and it is not currently applied in the model





Shipping emissions

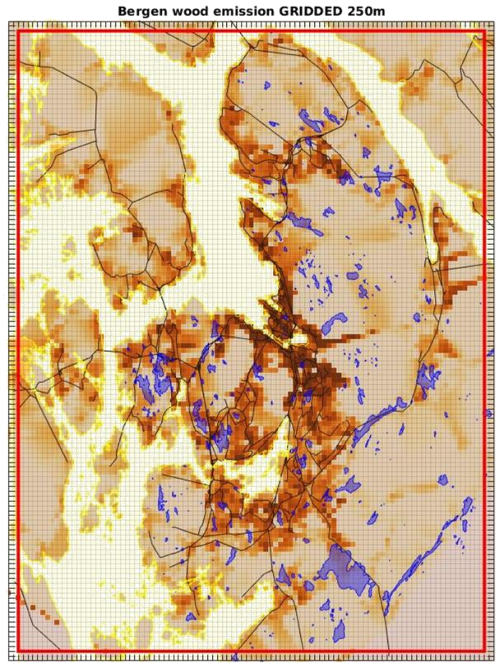
- AIS data (Automatic Identification System) is used for positional and movement information to determine exhaust emissions for shipping (kystverket.no)
- It is assumed that while AIS is turned on then the ships motors, or generators, are working. Emissions are determined from boat/engine type and speed
- Errors occur where land line electricity is available
- Heights of the emissions are not included in the AIS data
- Emissions are based on 2017 data. Monthly means and daily cycles each month are calculated on 250 m grids

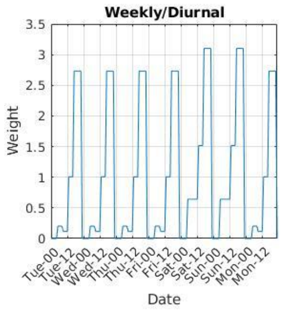
https://kart.kystverket.no/

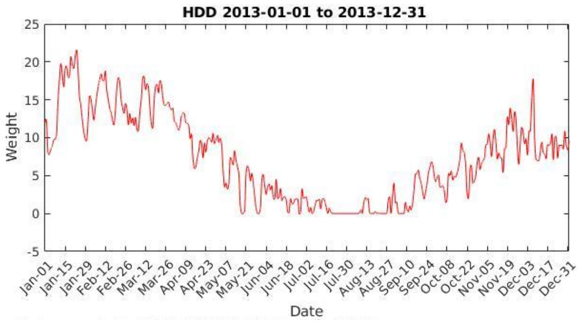
https://www.tu.no/artikler/bergen-havn-far-sin-forste-stikkontakt-for-skip/193813

Residential wood burning emissions

- New wood burning emission data has been provided by NILU (MetVed model)
- Uses a range of new data sources to better distribute wood burning emissions on a 250 m grid for all of Norway
- Uses ‘heating degree days’ (temperature dependency) to adjust the emissions on a daily basis







* Images supplied by Susana López-Aparicio, NILU

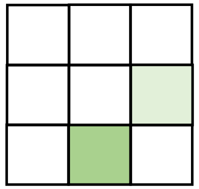
Industrial emissions

- Emission data for 300 industrial sites are available through Statistisk sentralbyrå (SSB) and Miljødirektoratet (www.norskeutslipp.no)
- Only total annual emissions are provided
- For PM only total particle emissions are provided (size unspecified)
- Lacking metadata (emission height, flow rate, temperature, detailed position of emission sources etc.) and temporal profiles
- Effective mission height set to 100 m for all industries

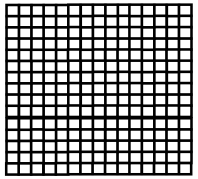
http://nordnorskdebatt.no/article/enig-tro-saltfjellet-faller
https://www.sa.no/nyhet/borregaard/miljo/na-skal-lufta-i-sarpsborg-bli-renere-takket-vare-denne-milioninvesteringen/s/5-46-421438

Terms and concepts

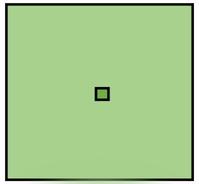
- **'Grid'** is the calculation grid for EMEP (2.5 km for Norway)



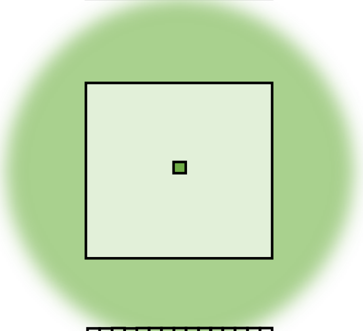
- **'Sub-grid'** is the uEMEP emission and concentration grid that is much smaller than the EMEP grid (250 – 50 m)



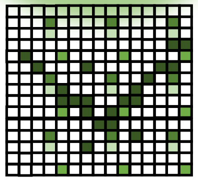
- **'Local region'** is the area surrounding an uEMEP sub-grid where the uEMEP calculations are done (10 x 10 km^2)



- **'Non-local'** includes all EMEP modelled concentrations originating from emissions outside the local region **and** not included in uEMEP

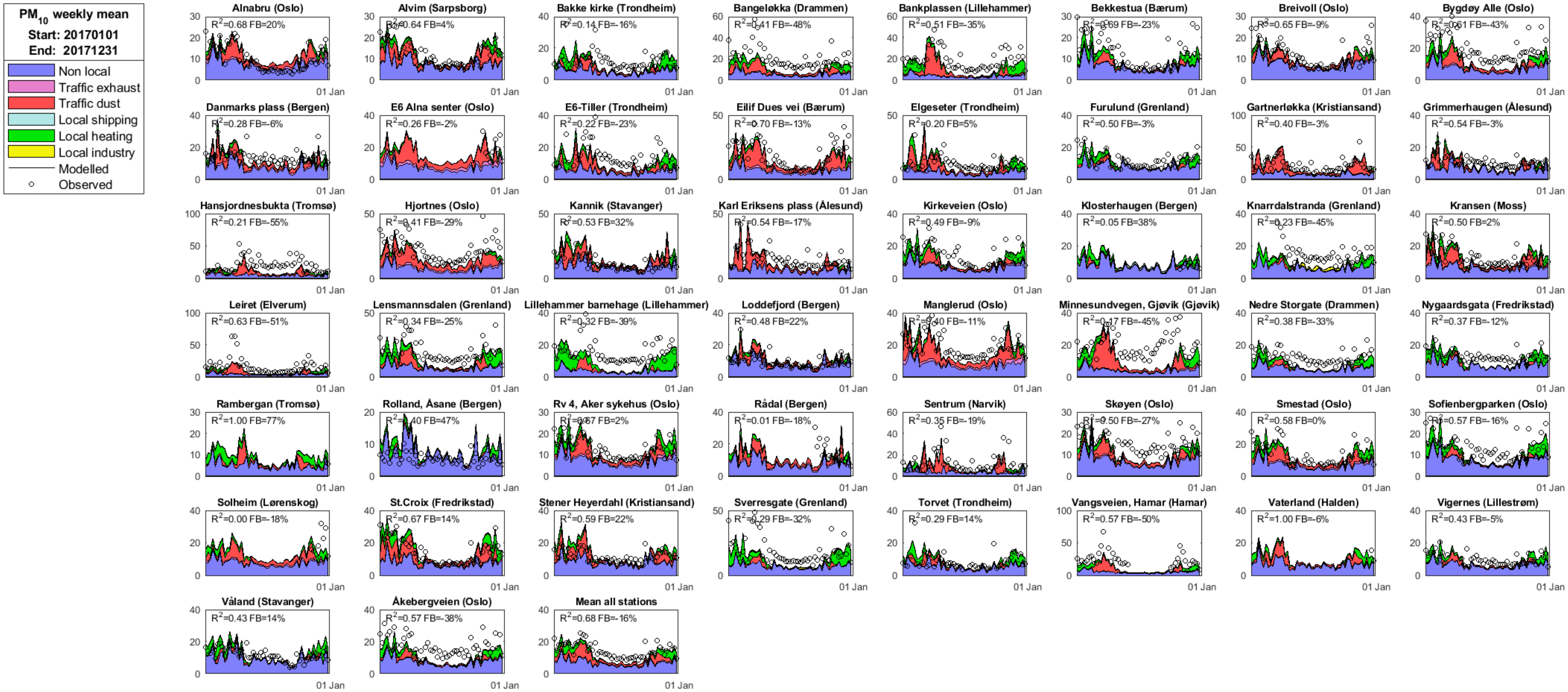


- **'Local'** means all uEMEP modelled concentrations from emissions within the 'local region'

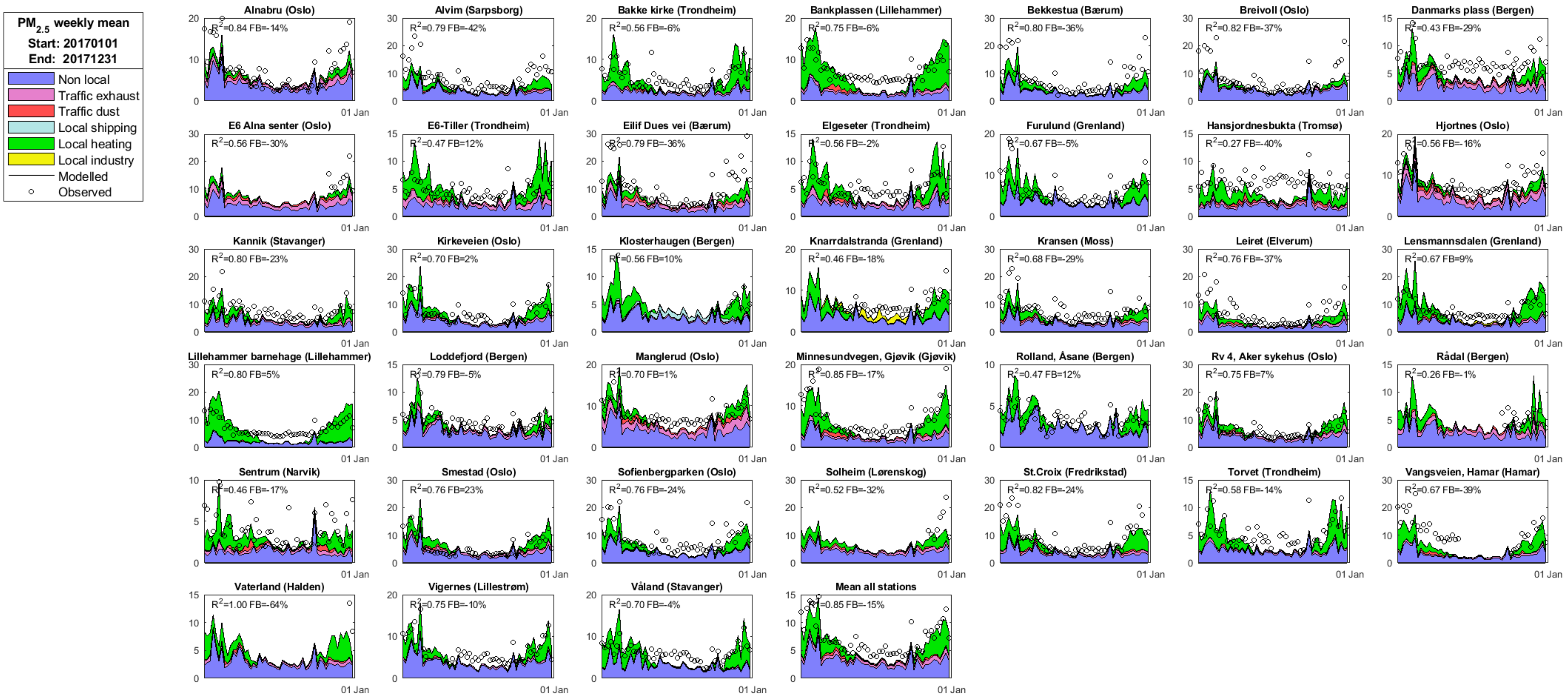


Forecast validation PM_{10} 2017:

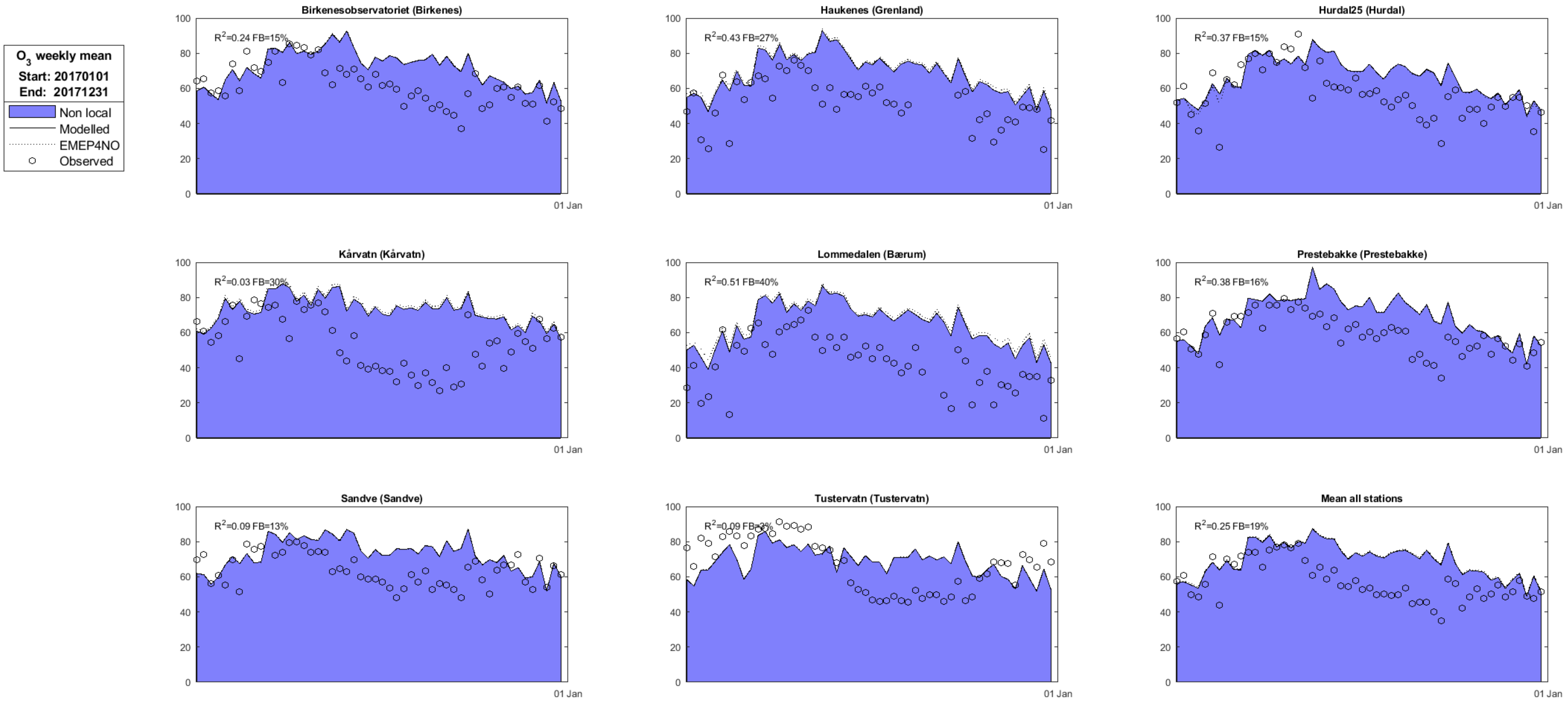
all stations, weekly means



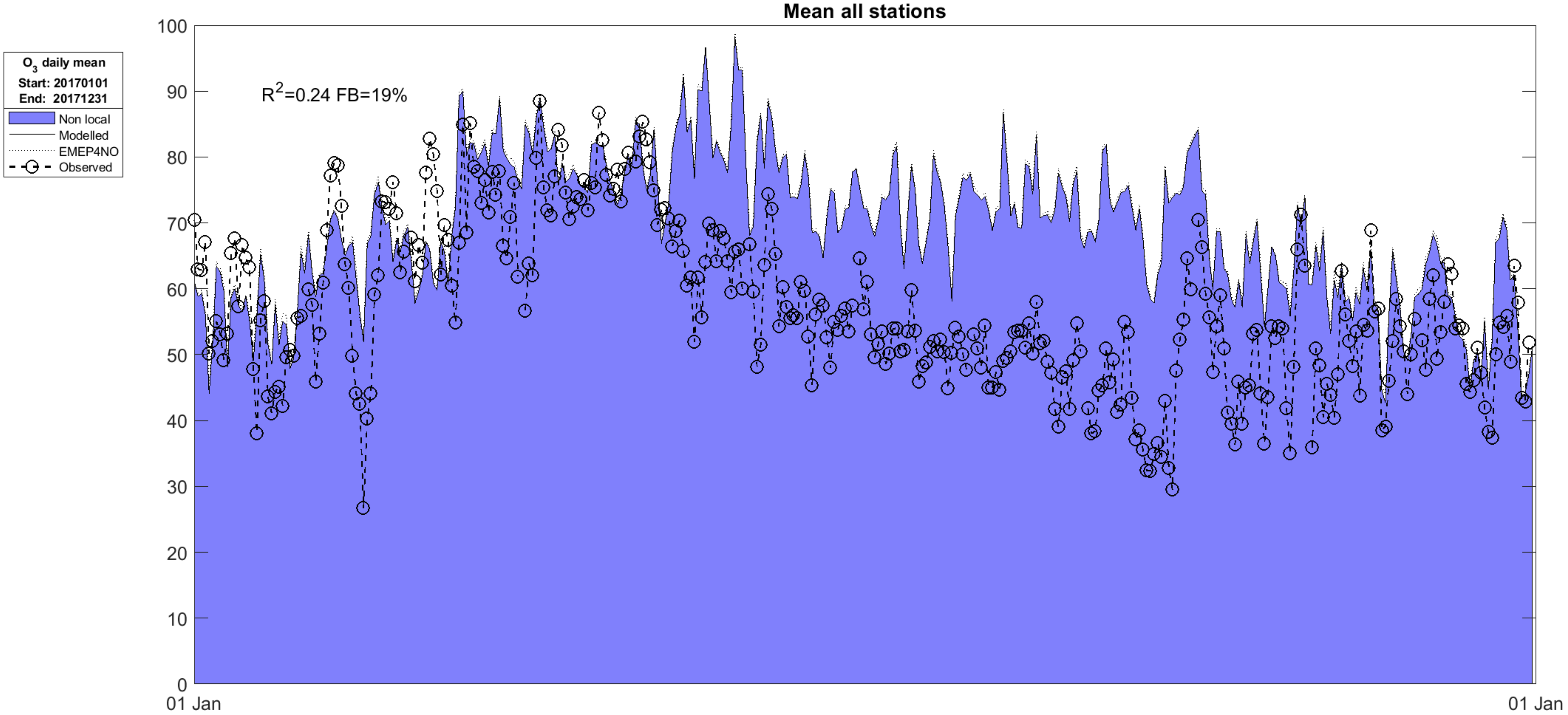
Forecast validation $PM_{2.5}$ 2017: all stations, weekly means



Forecast validation O_3 2017: all stations, weekly means



Forecast validation O_3 2017: mean all stations, daily mean



The EMEP model

- The EMEP model is used to calculate concentrations for Europe (~ 10 km) and provides boundary conditions for the Norwegian calculation
- The EMEP model is applied over Norway (2.5 km) using the meteorological data from the Arome-MetCOOP model (the same model that provides forecast information for Yr)
- Within the EMEP model is a routine that calculates how much the emissions from each grid contribute to it and its surrounding grids (**'local fraction'**)
- The 'local fraction' information allows us to place the high resolution uEMEP anywhere within EMEP by replacing the **'local region'** EMEP grids with uEMEP **'local'** sub-grids and avoid **double counting** of emissions