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Downscaling of the EMEP model using *u*EMEP: where scales meet

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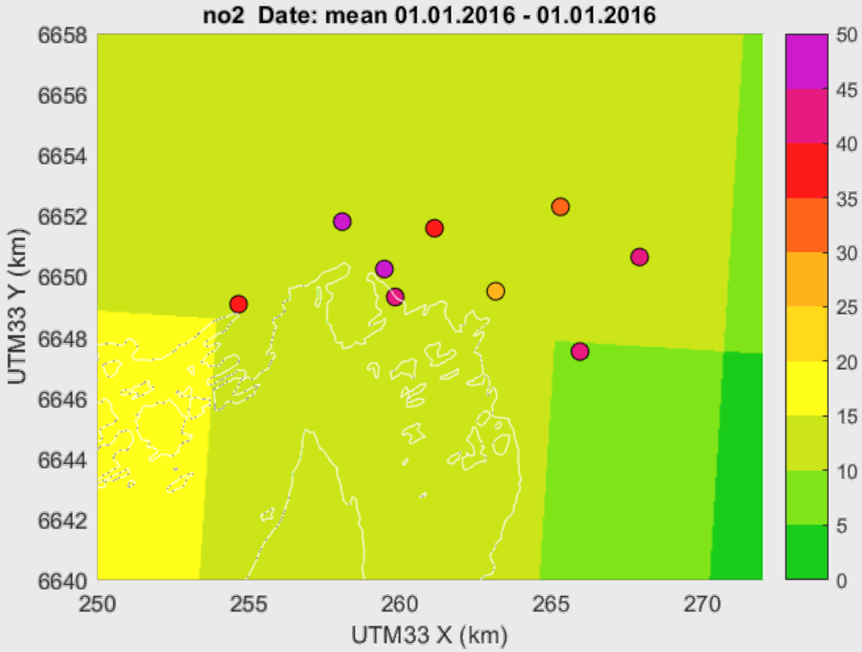
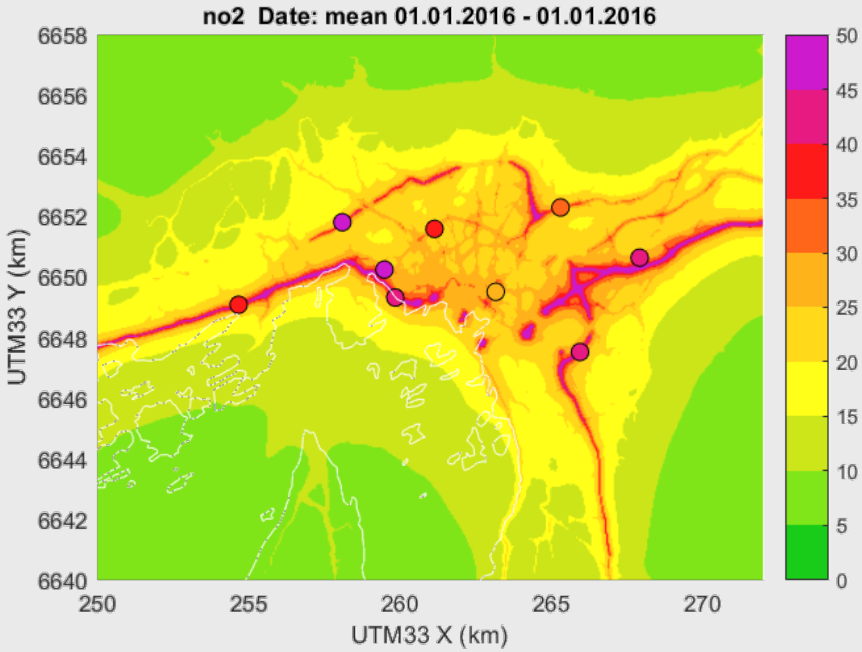
20.04.2018

Results



Oslo annual mean NO_2 EMEP (0.1º)

Oslo annual mean NO_2 *u*EMEP (50 m)



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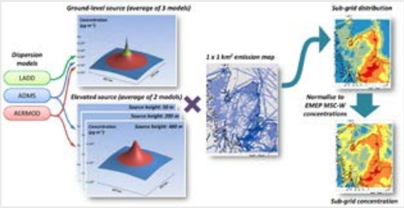
Overview

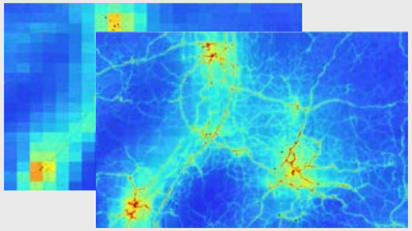
- Much time and effort has been put into the development of regional scale modelling
- These models now span many scales, e.g. EMEP is used on the global scale and down to 1 - 2 km (EMEP4UK, EMEP4NO)
- Even so, these models cannot resolve local near source gradients (e.g. roads) and cannot be validated by stations near to sources
- However, it is possible to cover large regions at high resolution using downscaling or redistribution techniques built into, or appended to, the regional models
- Such methods are often referred to as kernel techniques as they redistribute high resolution proxy or emission data based on a moving kernel (really just a Gaussian dispersion model)
- Application of these methods reveal the discrepancies between local and regional emission inventory methods
- In order to span all scales in future modelling then these emission discrepancies need to be removed

Recent activities in kernel downscaling

- Theobold et al. (2016) 1 km sub-grid within EMEP 50 km but did not account for local or non-local contributions

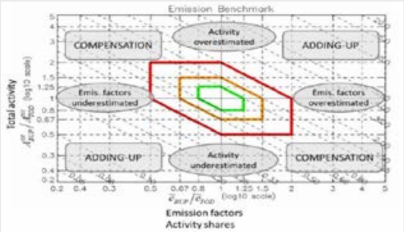


- Maiheu et al. (2017) European wide kernel downscaling (125 m) for traffic emissions using Chimere (Presentation Stijn Janssen on Friday)



- Sherpa city. European wide user interface (in development) using kernel downscaling and Chimere

- FAIRMODE emission comparison maps have shown discrepancies across Europe in top down and bottom up emissions (Enrico Pisoni and Susana Lopez-Aparicio presentations Tuesday)



- … and *u*EMEP

Theobald, M. R., sub-grid model for improving the spatial resolution of air quality modelling at a European scale, GSimpson, D., and Vieno, M.: A eoscientific Model Development Discussions, 2016, 1–22, doi:10.5194/gmd-2016-160, URL http://www. geosci-model-dev-discuss.net/gmd-2016-160/, 2016.

Improved Methodologies for NO2 Exposure Assessment in the EU (2017) Maiheu Bino, Wouter Lefebvre, Heather Walton, David Dajnak, Stijn Janssen, Martin Williams, Lisa Blyth, Sean Beevers. EC Report no.: 2017/RMA/R/1250. http://ec.europa.eu/environment/air/pdf/NO2%20exposure%20final%20report.pdf

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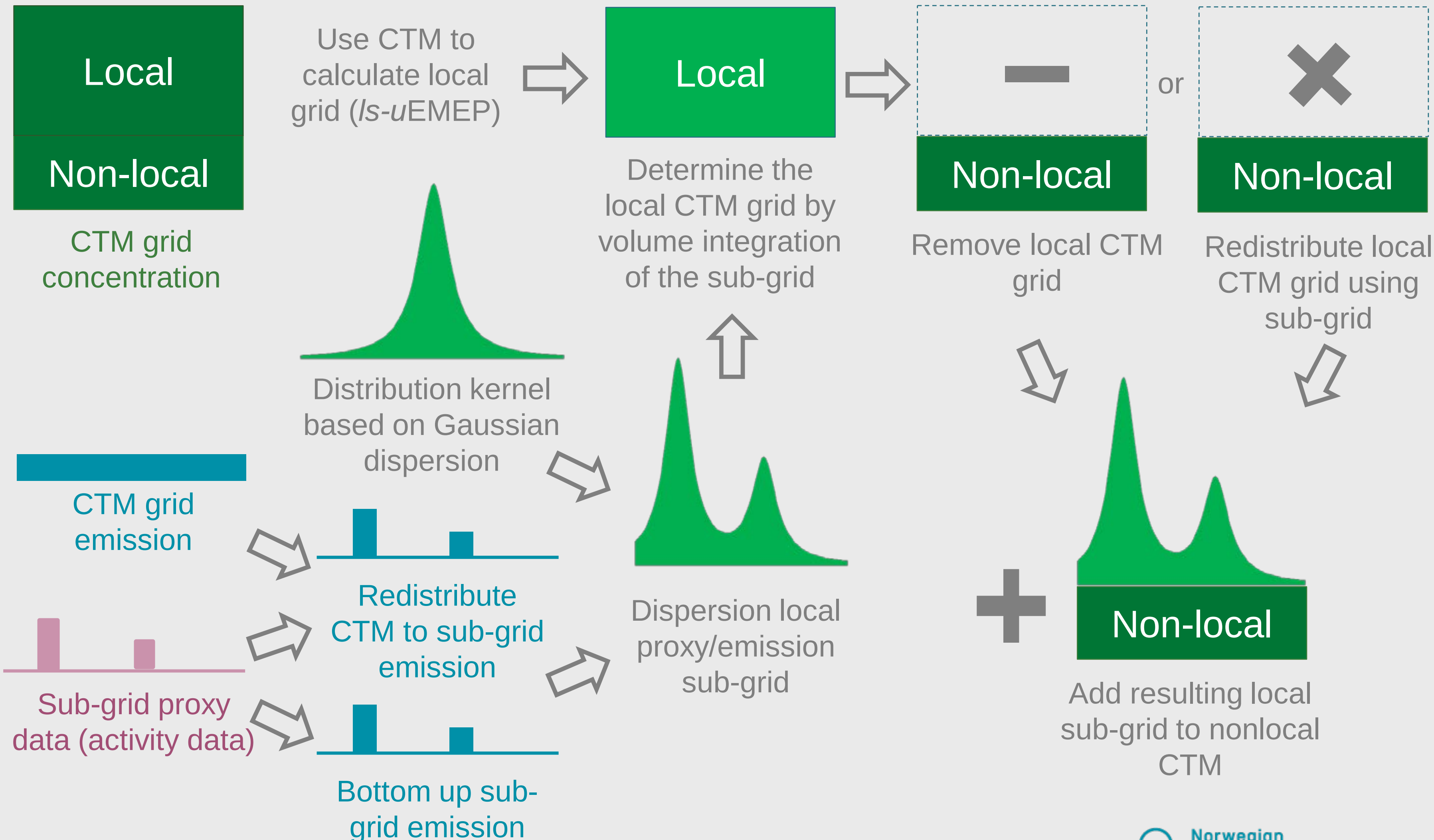
A brief overview kernel downscaling methodology



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Advantages of the kernel methodology

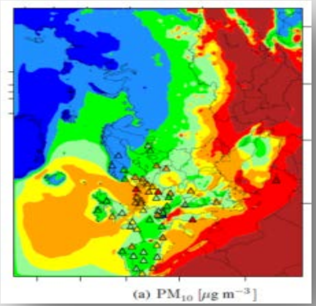
- The gridded CTM concentration can be conserved, out of respect for regional modellers
- If the removal of the local CTM contribution is properly done then all double counting is avoided
- Instead of using CTMs as boundary conditions then local models can be laid seamlessly on top of existing CTMs allowing large regions to be modelled at high resolution

- For seamless application then the aggregated CTM grid emissions should be the same as the sub-grid distribution
- Only appropriate for non-reactive primary emissions (NO_2 post processing possible)

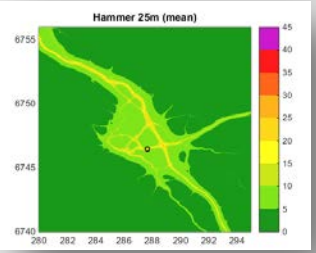
*u*EMEP

- *u*EMEP (urban EMEP) consists of two parts

- A method for calculating the **local source** contribution of gridded emissions within EMEP has been developed (*ls*-*u*EMEP)



- A method for **downscaling** the local source contributions, by **redistribution** or **replacement**, to high resolution sub-grids (*ds*-*u*EMEP) of ~ 50 m



- Can be applied on both hourly and annual data and on all EMEP resolutions (e.g. 0.1^{o} and 2.5 km)

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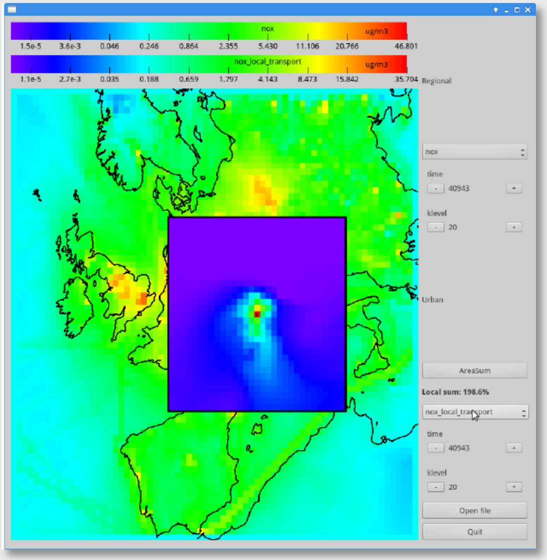
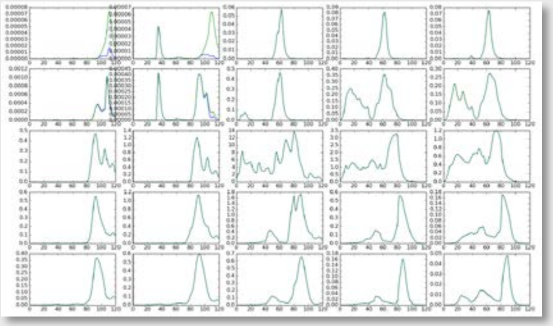
Local source *ls-u*EMEP

- Built into the EMEP model, source concentration fluxes are followed through the model domain to the surrounding grids
- With this we know the contribution to each grid from all the neighbouring grids, e.g. 5 x 5 or 20 x 20 surrounding grids
- Knowing this we can calculate **source contributions** to or from the surrounding grids
- And/or use this information to **downscale** only the local source contribution





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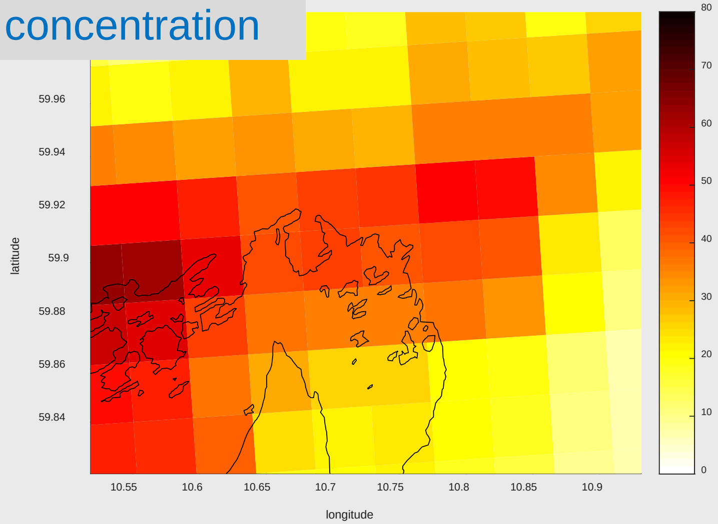
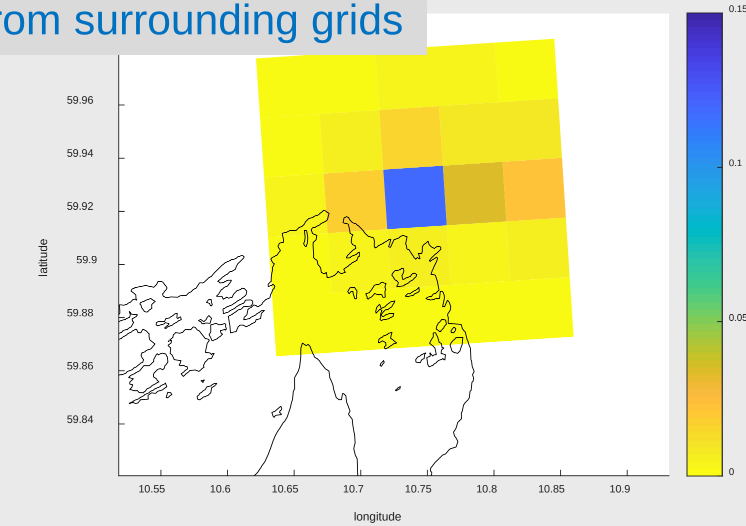
Example for traffic in Oslo using *ls-u*EMEP (NO_x)

2 day forecast average at 2.5 km resolution

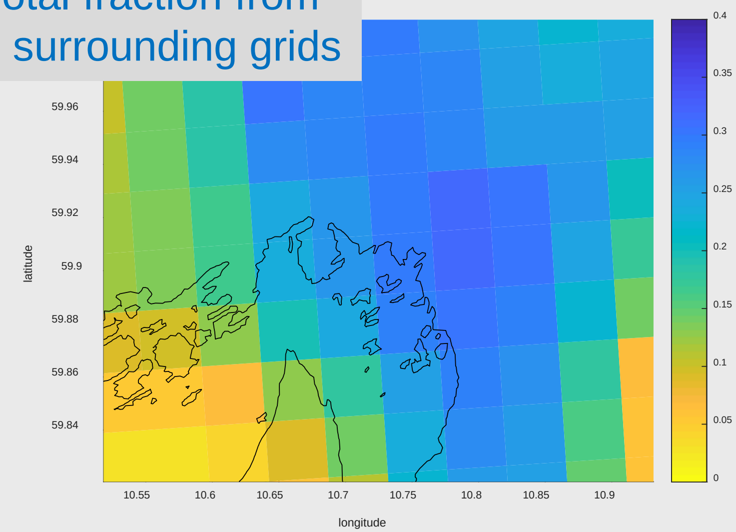
Total NO_x concentration



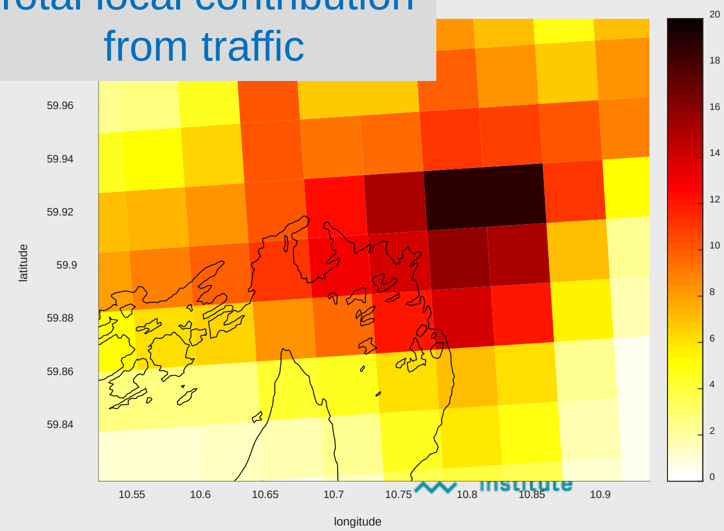
Fractional contribution from surrounding grids



Total fraction from all surrounding grids



Total local contribution from traffic



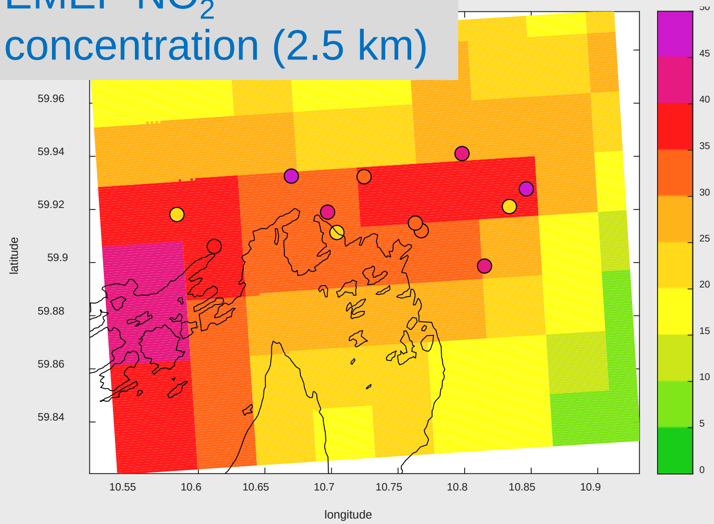
Downscaling *ds-u*EMEP

- Standard Gaussian models are applied on either annual mean or hourly data to disperse sub-grid emissions or proxy data
- These are then used to either **replace** the calculated *ls-u*EMEP concentration or to **redistribute** it
- Three examples will be shown:
  1. The sub-grid Gaussian dispersion is volume integrated over the EMEP grid and the sub-grid concentrations are normalised and **redistributed** at surface level (preserves volume average grid concentration)
  2. The EMEP gridded **emissions are redistributed** over the sub-grid emission data and the sub-grid **dispersion replaces** the EMEP local source contribution (preserves volume average grid concentration only if dispersion and advection is the same)
  3. **Independent emissions** are used and the sub-grid **dispersion replaces** the EMEP local source contribution (does not preserve volume average grid concentrations)

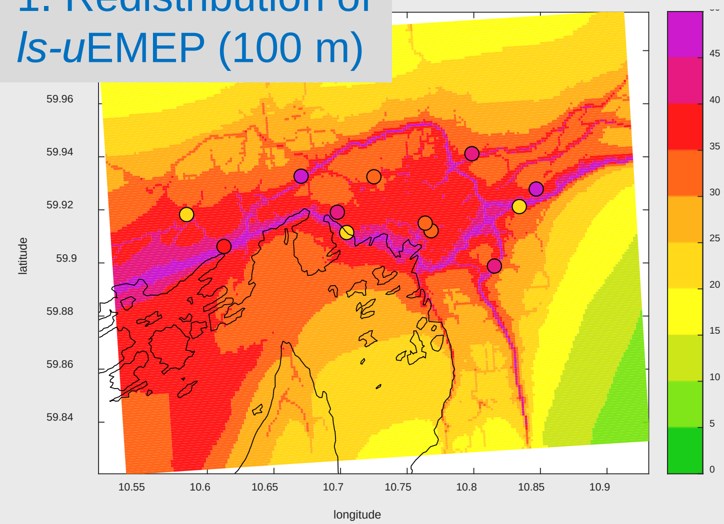
Example for forecast in Oslo using *ds-u*EMEP (NO_x)

2 day forecast average at 2.5 km resolution

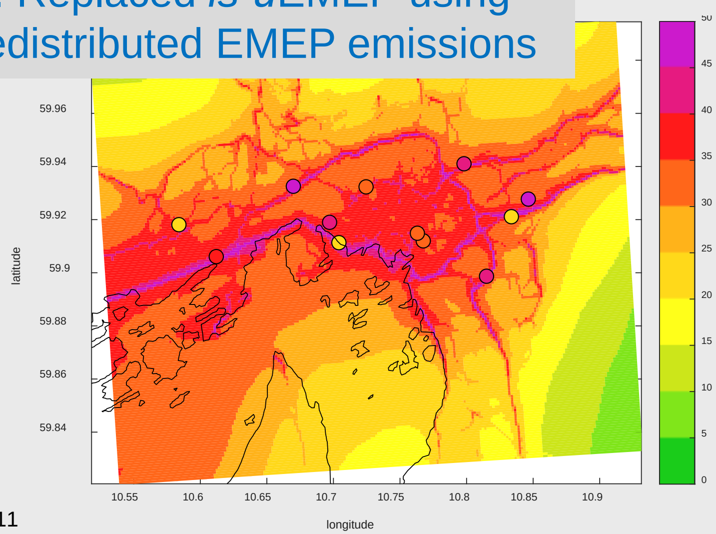
EMEP NO_2 concentration (2.5 km)



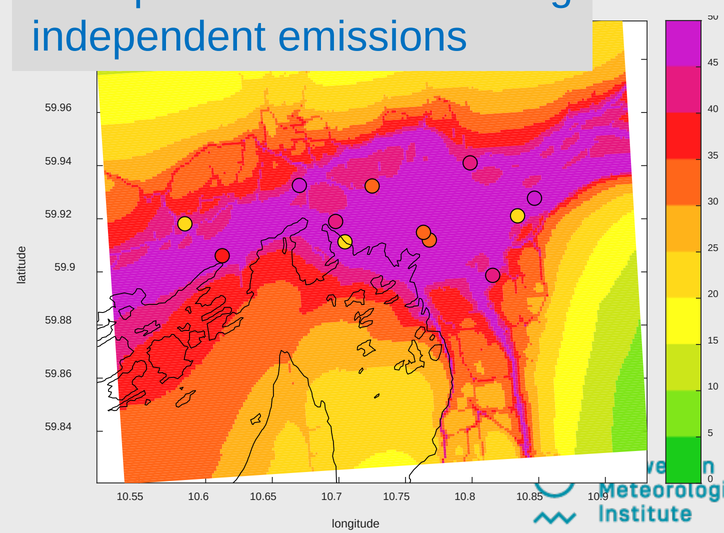
1. Redistribution of *ls-u*EMEP (100 m)



2. Replaced *ls-u*EMEP using redistributed EMEP emissions



3. Replaced *ls-u*EMEP using independent emissions



Example calculations for Norway

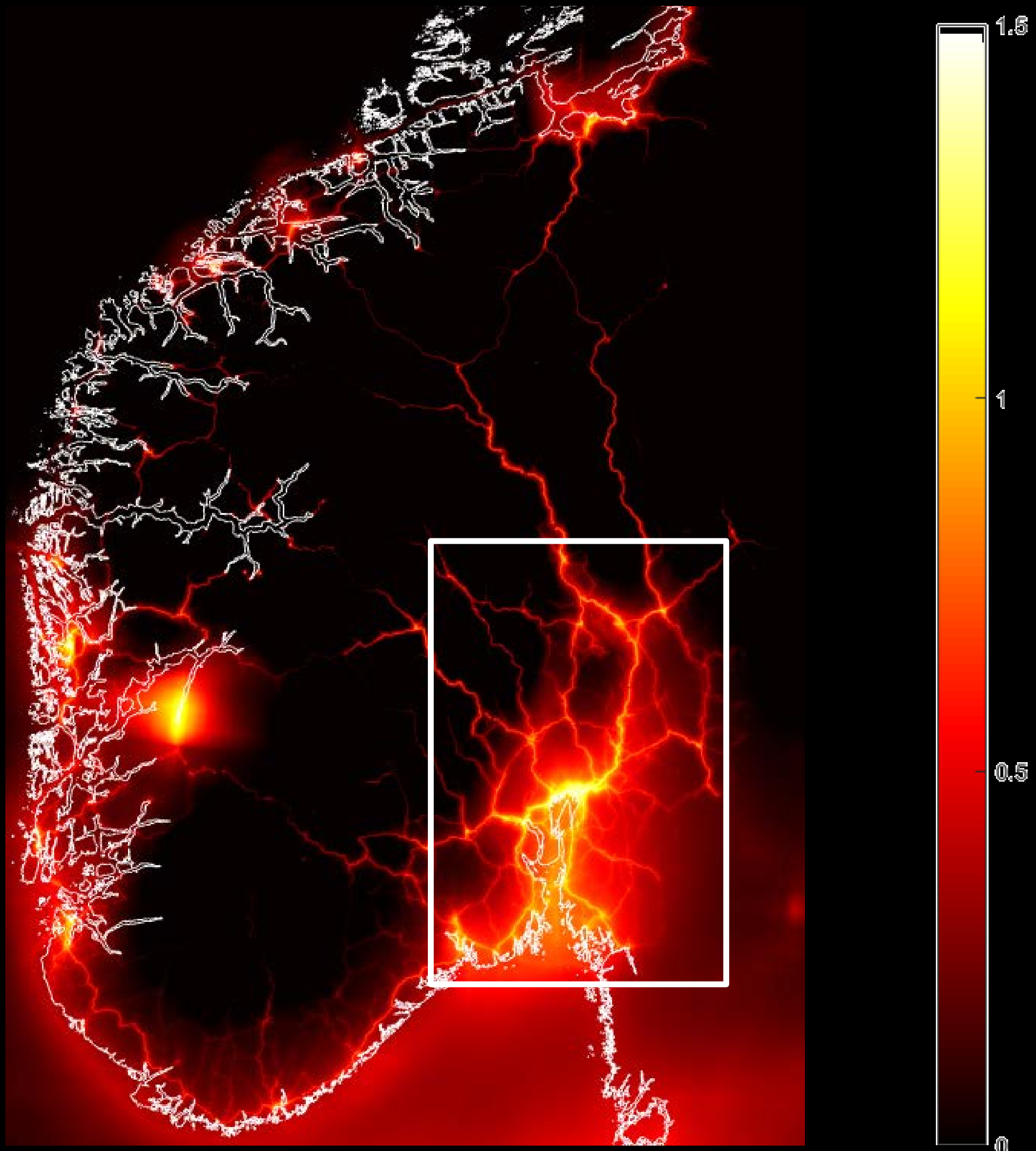
NO_2 annual mean

Annual mean NO_2 concentrations for Southern Norway

*u*EMEP calculation for traffic and shipping at 250 m

EMEP 0.1º

uEMEP 250 m

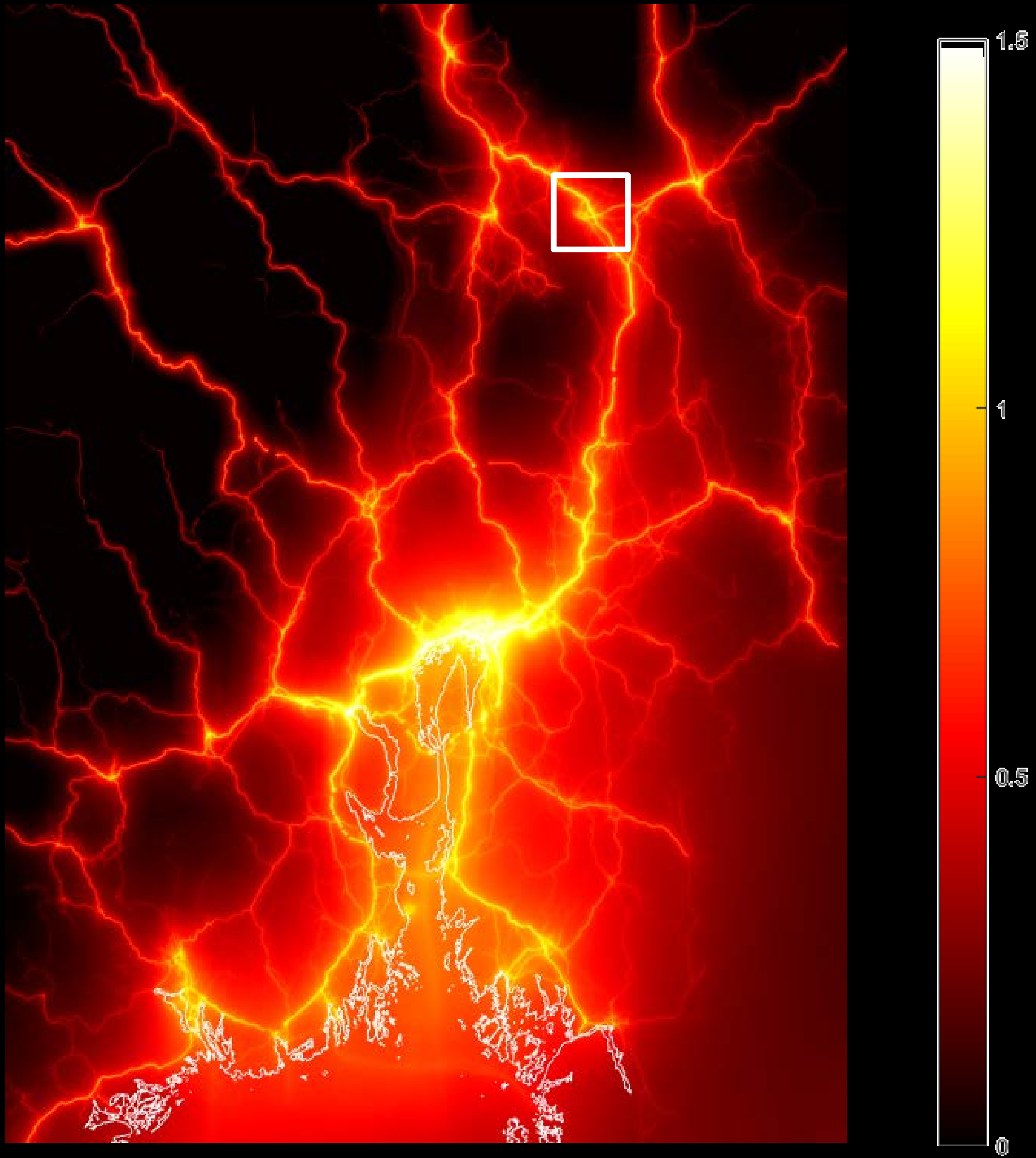


Scale is logarithmic (log_{10}) from 1 to 30 ug/m^3

Annual mean NO_2 concentrations for Oslo region
*u*EMEP calculation for traffic and shipping at 100 m

EMEP 0.1°

uEMEP 100 m

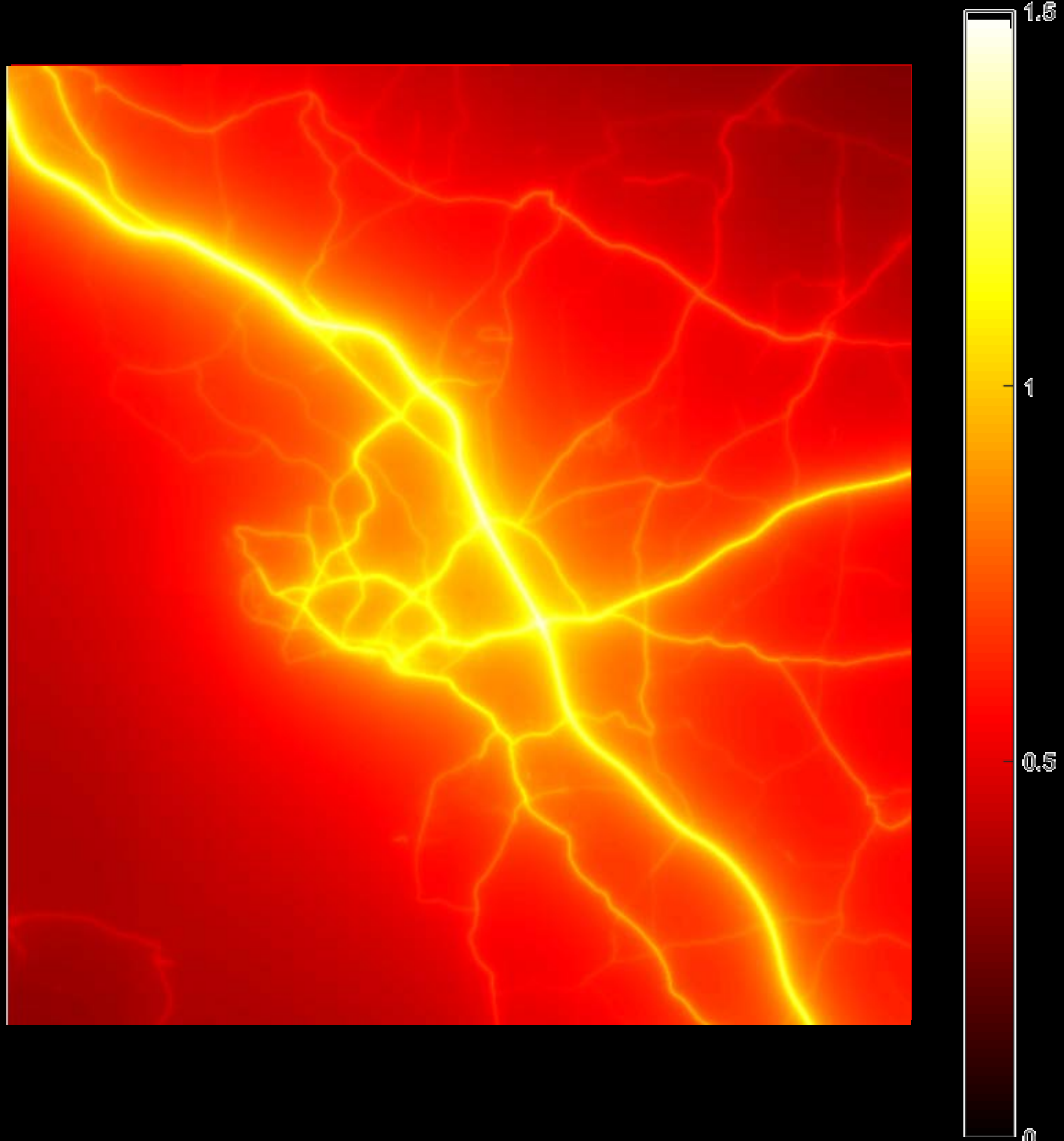


Scale is logarithmic ($\log_{10}$)
from 1 to 30 ug/m^3

Annual mean NO_2 concentrations for Hamar
*u*EMEP calculation for traffic and shipping at 25 m

EMEP 0.1º

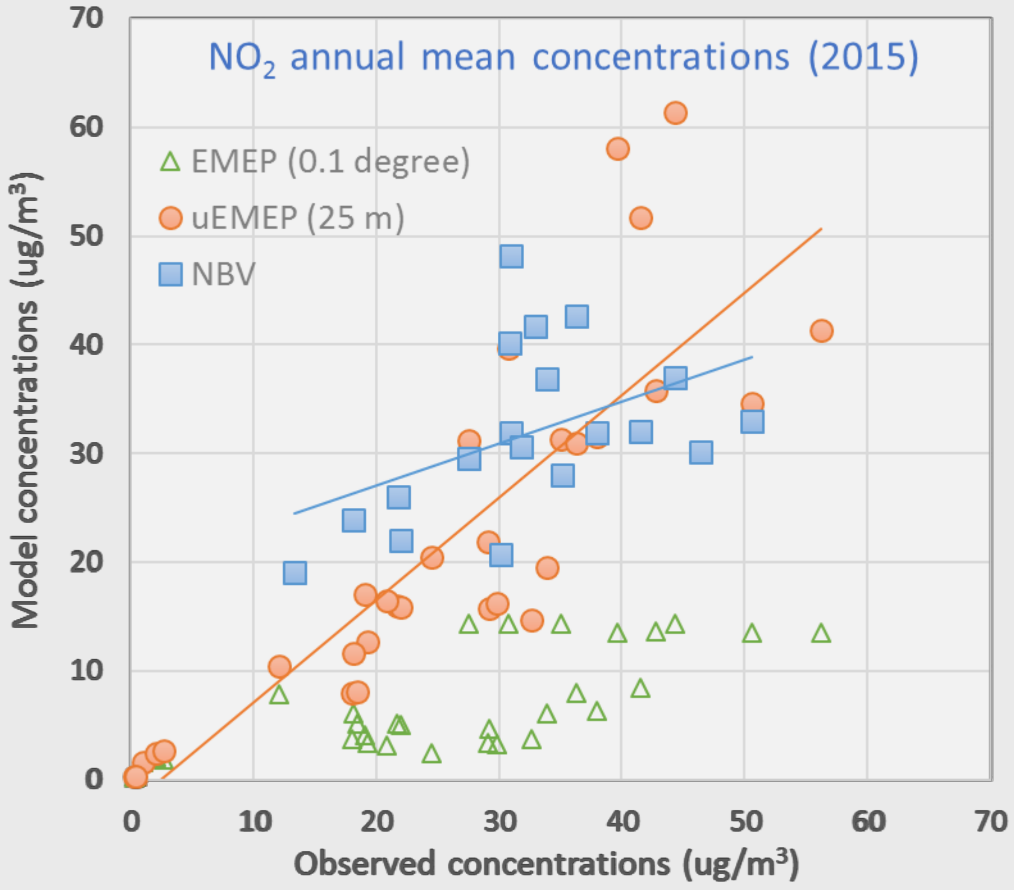
uEMEP 25 m



Scale is logarithmic (log_{10})
from 1 to 30 ug/m³

Annual mean NO_2 Airbase stations Norway

Comparison EMEP (0.1º), *u*EMEP and existing (NBV)



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Example in The Netherlands

NH_3 annual mean based on RIVM high resolution emission data

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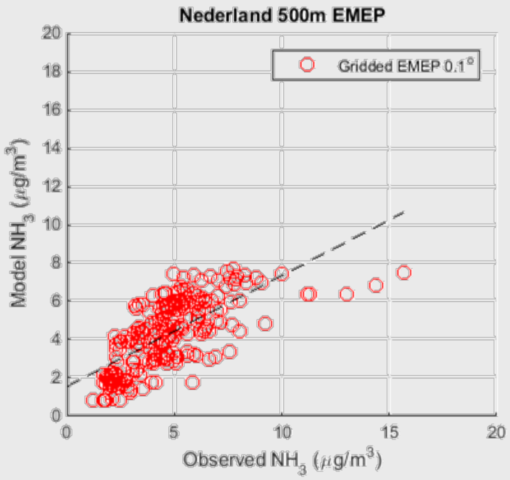
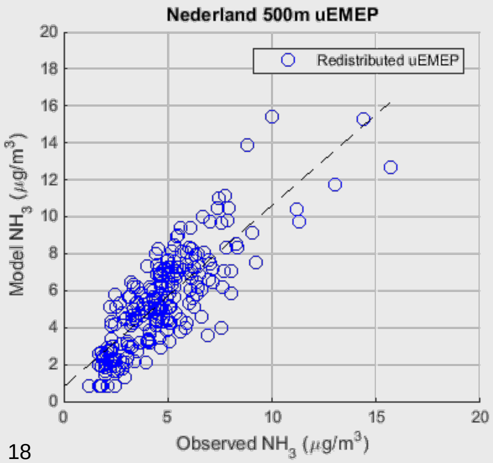
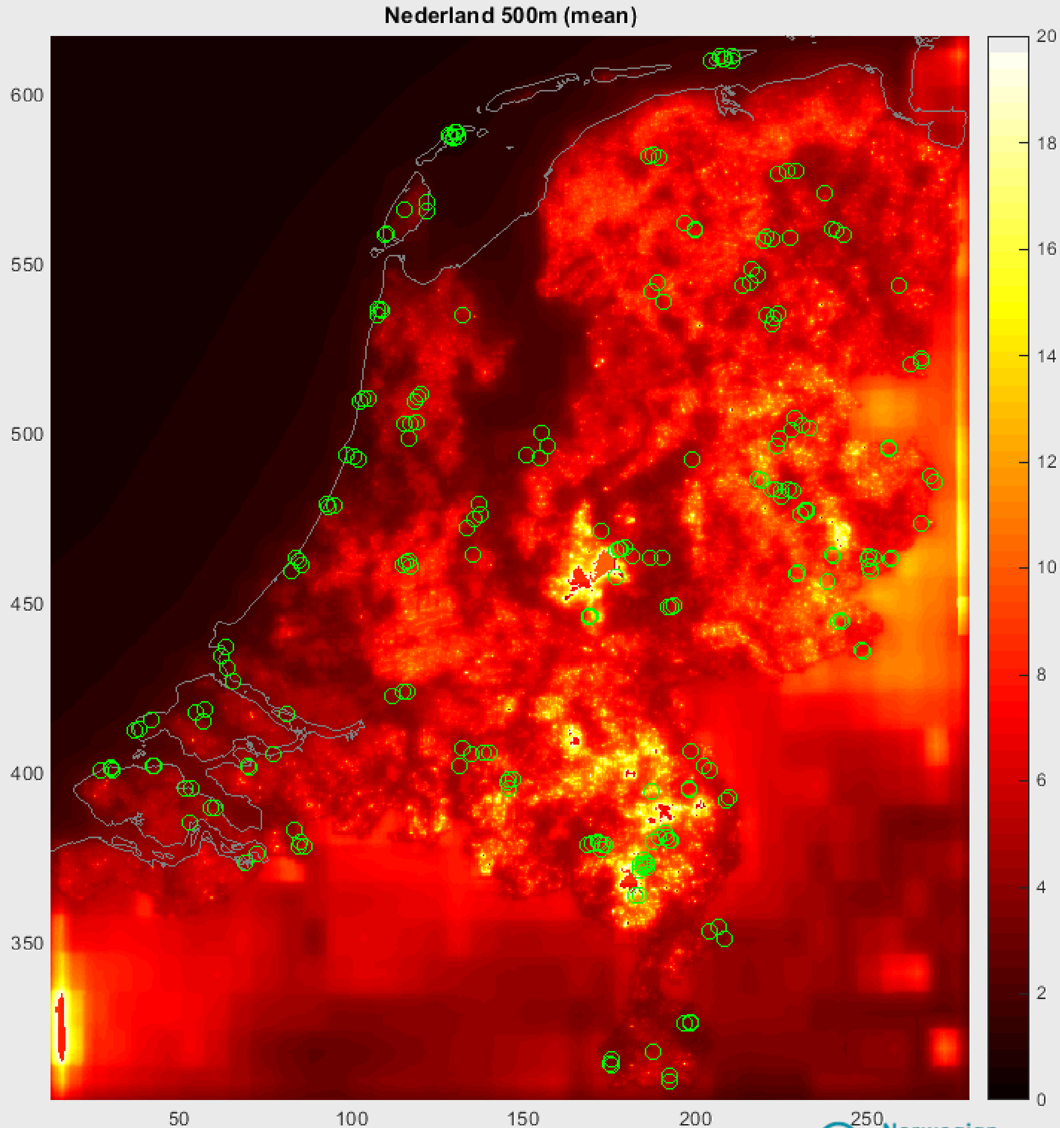
500 m *u*EMEP with RIVM NH_3 emissions in EMEP

EMEP 0.1º R^2=0.43



*u*EMEP 500 m R^2=0.67





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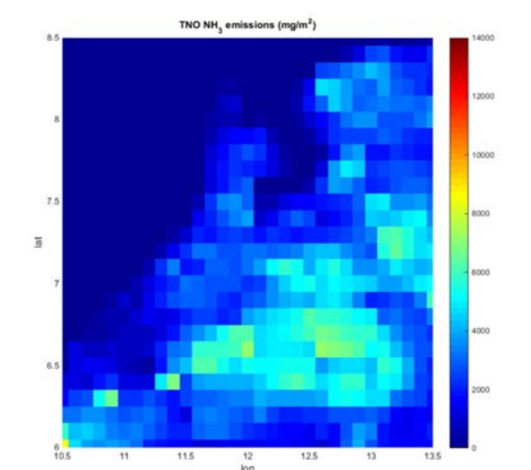
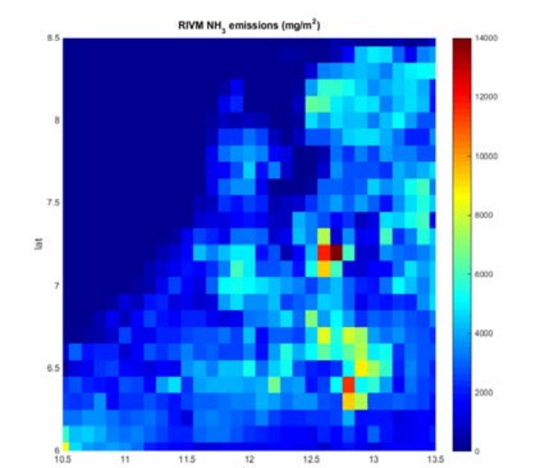
Poorly correlated NH_3 emissions in The Netherlands

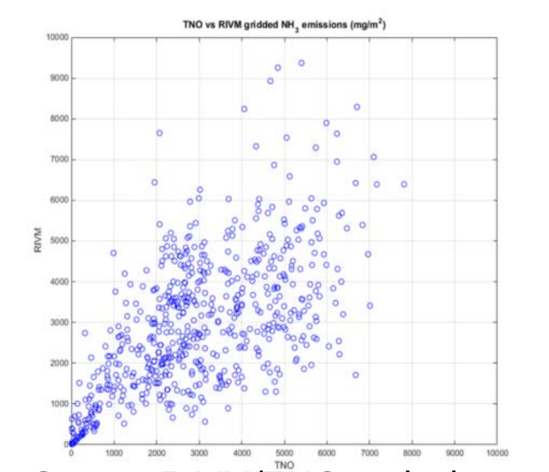
- Two emissions datasets are available for NH_3 in the Netherlands:
  - TNO-MAC3 European emission database (0.1^o)
  - The original emissions from RIVM (1 km + individual farm buildings)
- Spatial correlation between RIVM and TNO-MAC3 emissions is poor (R^2=0.38), but the total emissions are the same



TNO-MAC3 0.1^o emissions



RIVM emissions



Scatter RIVM/TNO emissions

- When TNO-MACC3 emissions are used in EMEP then *u*EMEP spatial correlation decreases from R^2 = 0.67 to R^2=0.43

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A summary of *u*EMEP

- The local source calculation in *ls*-*u*EMEP can be used for downscaling but also for source allocation within local regions
- *ls*-*u*EMEP is part of the latest open source EMEP/MSC-W code (https://github.com/metno/emep-ctm)

- The downscaling part of *u*EMEP (*ds*-*u*EMEP) can be applied on annual data (rotationally homogenous Gaussian model) or hourly data (standard Gaussian plume)
- Can be applied anywhere in Norway (have complete proxy data for traffic and shipping) for NO_2 and provides similar results to existing local models
- In The Netherlands NH_3 downscaling provides similar results to existing local models
- Still under development with aim to implement over larger regions but appropriate proxy data on European scale is not directly available

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A general summary

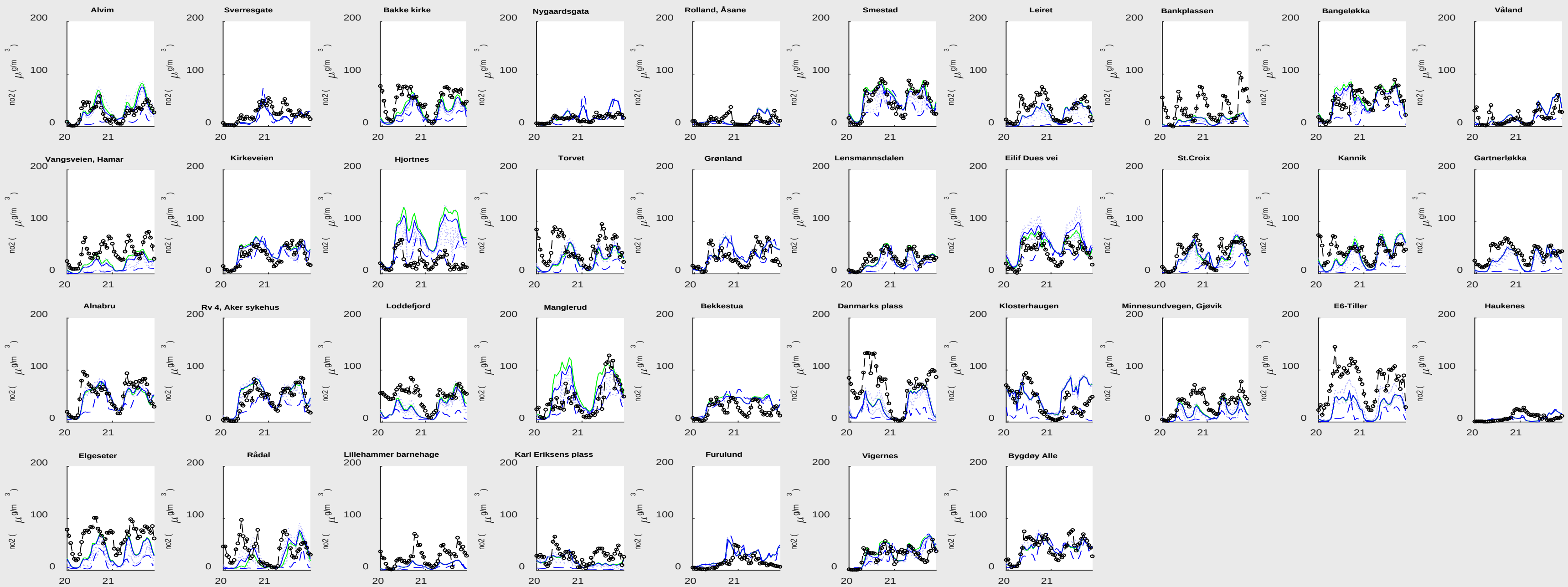
- From a regional scale perspective sub-grid downscaling of CTM grids is like magic, allowing regional models to produce local scale concentrations
- From a local scale perspective it is just simple Gaussian dispersion with a different way of including background concentrations
- So what is the advantage of this?
- Given *appropriate* emission/proxy data then large regions can be modelled at high resolution (country, continent)
- It makes local scale modelling available for regional modellers allowing ‘scale closure’ for regional models
- It clearly reveals discrepancies between regional and local emissions and will help, in the long run, to reduce these inconsistencies

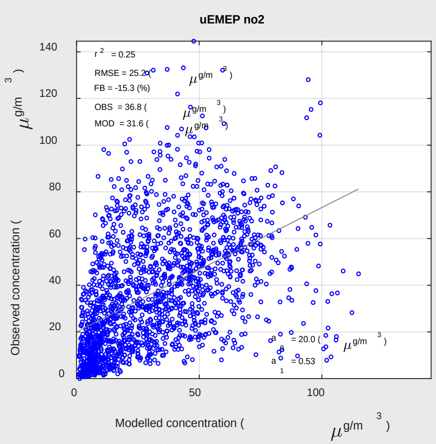
- What is an *appropriate* emission database for this application?
- An appropriate emission database is one that can be aggregated or disaggregated consistently, that includes not just emissions but the underlying data used to make the emissions

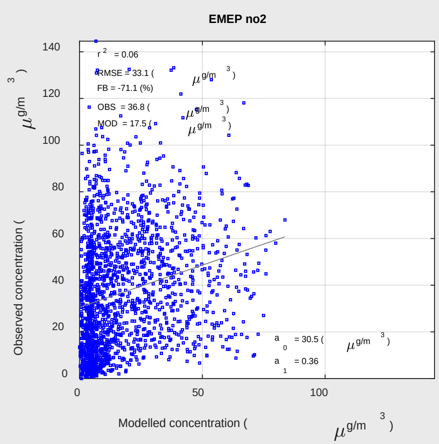
Thank you

2 day forecast for NO_2 at 25 m for all stations in Norway

Comparison *u*EMEP and EMEP (2.5 km)







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