Norwegian Meteorological Institute

AIRQUIP

*u*EMEP: concept and application

Bruce Rolstad Denby

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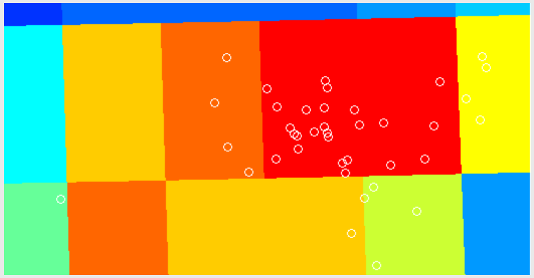
Hilde Fagerli

AIRQUIP kickoff meeting 19.04.2017

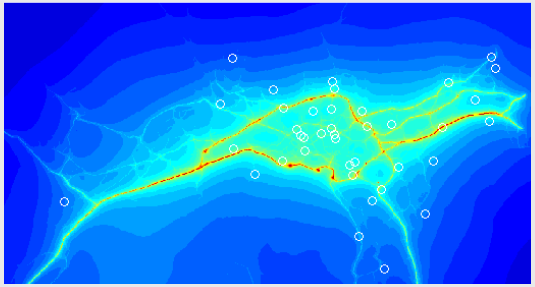
What is *u*EMEP ?

*u*EMEP is a methodology for calculating high resolution concentration fields (~ 50 m) from low resolution model data (~ 10 km)



To achieve this *u*EMEP requires relevant data at high spatial resolution that represents the spatial distribution of emissions (proxy emission data)

By redistributing the low resolution model concentrations using these high resolution proxy data then high resolution concentration fields can be calculated



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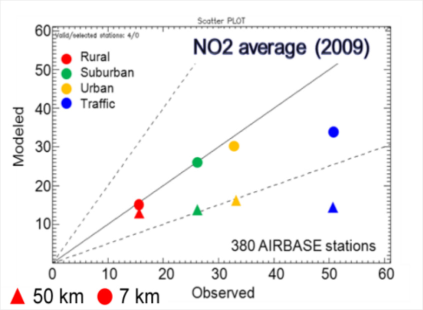
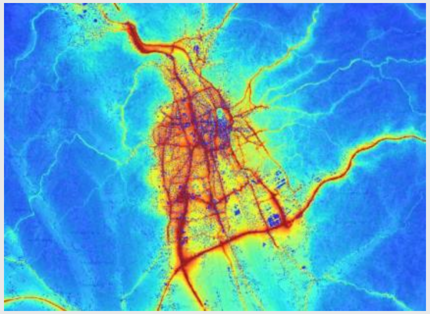
http://emep.int/mscw/index_mscw.html

Why do we need *u*EMEP?

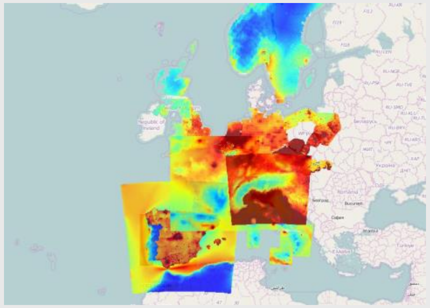
There is a need for high resolution concentration fields over large scales to calculate exposure for whole populations



To resolve the gradients in exposure near to local sources (e.g. roads) then a resolution of < 50 m is required



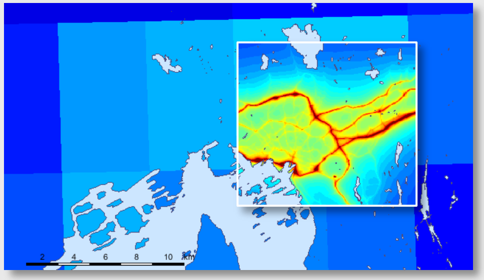
There are large inconsistencies between local (bottom up) and regional (top down) emissions inventories



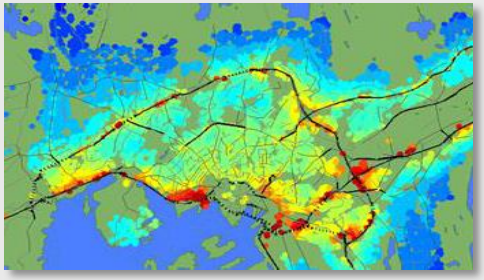
It is not possible to assess regional model emission inventories in urban areas due to the strong concentration gradients

What can *u*EMEP provide?

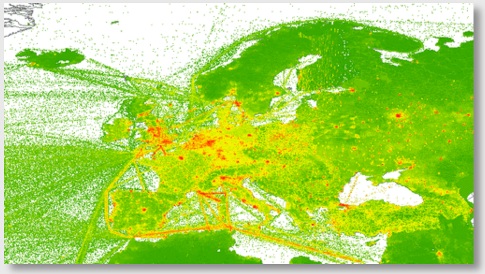
A consistent method for coupling scales in air quality modelling



A method for determining high resolution exposure for large population regions



A method for determining the quality of regional scale emission inventories in urban areas and for improving the compatibility of local and region emission inventories



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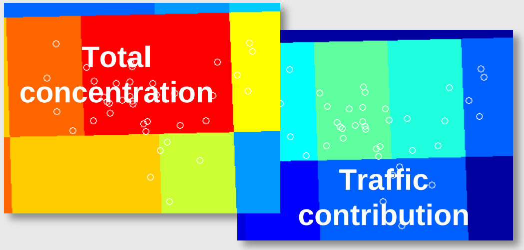
Glossary of terms

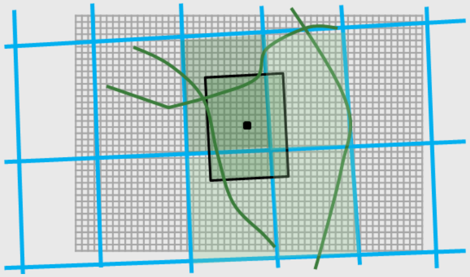
Term	Meaning
EMEP grid	Refers to the gridded emissions or concentrations of the regional scale model EMEP
EMEP local source contribution	Is the special calculation of the local emission source contribution in each EMEP grid. Also includes the contribution to neighbouring grids. Calculated internally during the EMEP calculation
***u*EMEP**	Is the whole downscaling methodology including local source contribution calculations in EMEP and the off line downscaling using Gaussian dispersion to the target sub-grid (sometimes *u*EMEP refers to just the last part)
Target sub-grid	Refers to the high resolution sub-grid that *u*EMEP downscales to
Proxy emission data	All high resolution data that can be used to redistribute EMEP grid concentrations. Can be emission data or just related to the spatial distribution of these data
Top down emissions	Aggregated emission data (country, province level) is disaggregated to finer scales using proxy distribution data
Bottom up emissions	Base level activity data is combined with emission factors to determine local direct emissions (e.g. industry emissions, road traffic emissions)
Moving window interpolation	Special interpolation method used in *u*EMEP for dealing with edge effects. Simulates a repositioning of the EMEP grid based on the position of the proxy emissions
TNO emissions	0.1^{o} emission database used by EMEP in CAMS forecast system

How does *u*EMEP work?

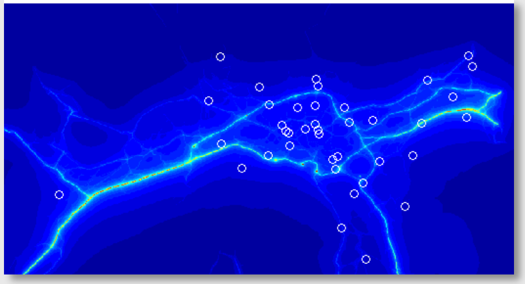
1. EMEP calculates and tracks the **local source contribution** in each EMEP grid, as well as the surrounding grids. It does this for every calculation time step.



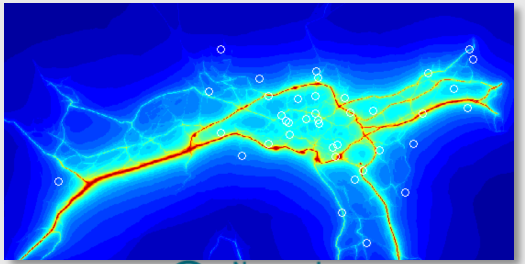
2. A **moving window** method is used to deal with 'edge effects' created near EMEP grid boundaries. This method simulates a repositioning of the EMEP grid centred on the sub-grid point that will be calculated



3. Proxy (or real) emission data are 'dispersed' using standard Gaussian methods, within each EMEP moving window grid, to each sub-grid. The **dispersed proxy emissions** are calculated at the surface and also integrated over the lowest EMEP grid to determine the grid volume average



4. The EMEP local source contribution is redistributed using the surface dispersion proxy, normalised with the grid volume average dispersion proxy, and the non-local EMEP grid concentration is added



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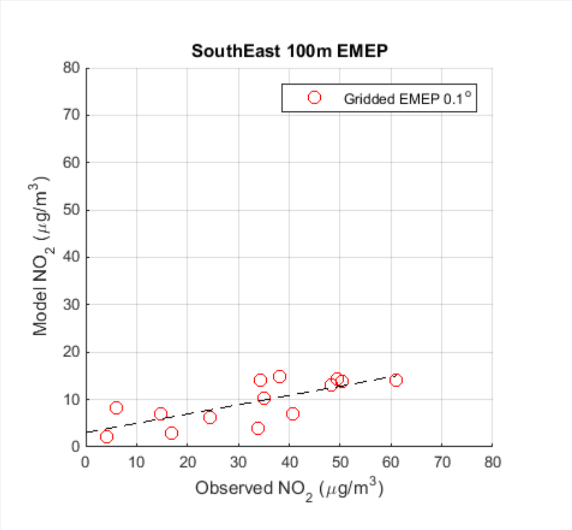
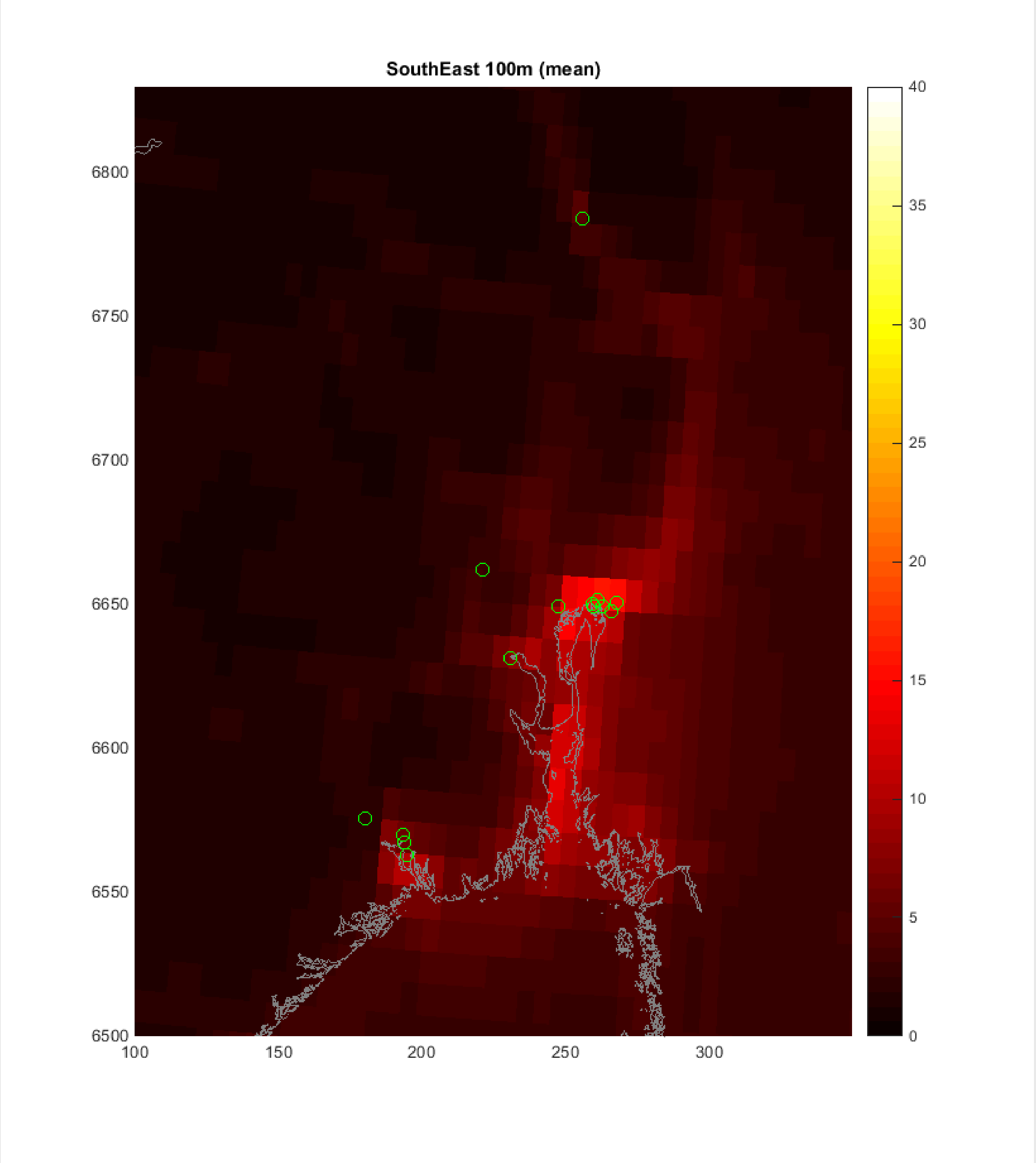
Examples in Norway

NO_2 annual mean concentration redistributed for traffic and shipping

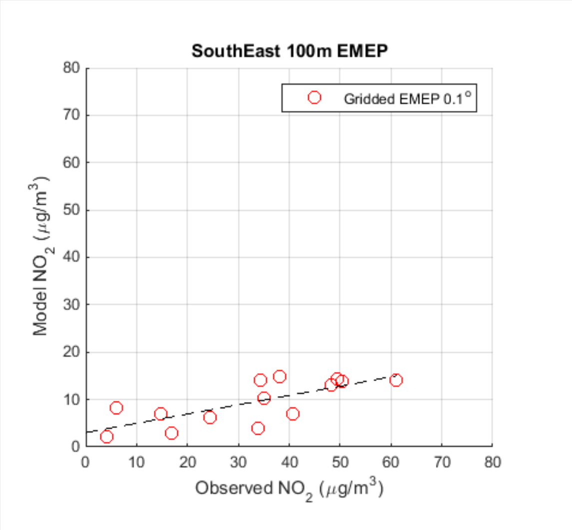
Østlandet NO_2 (2013)



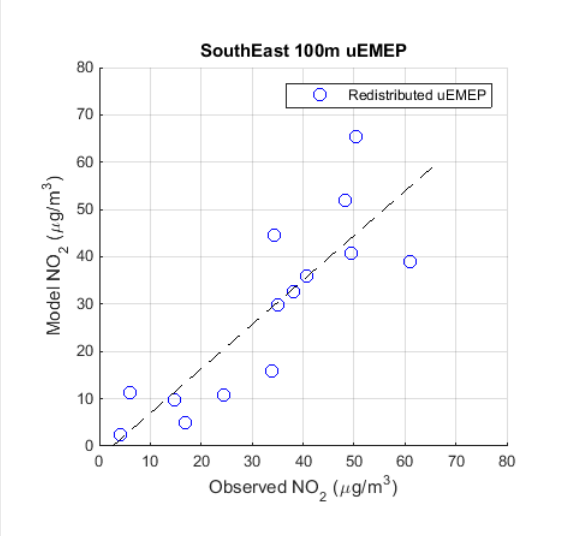
EMEP 0.1° (2013)



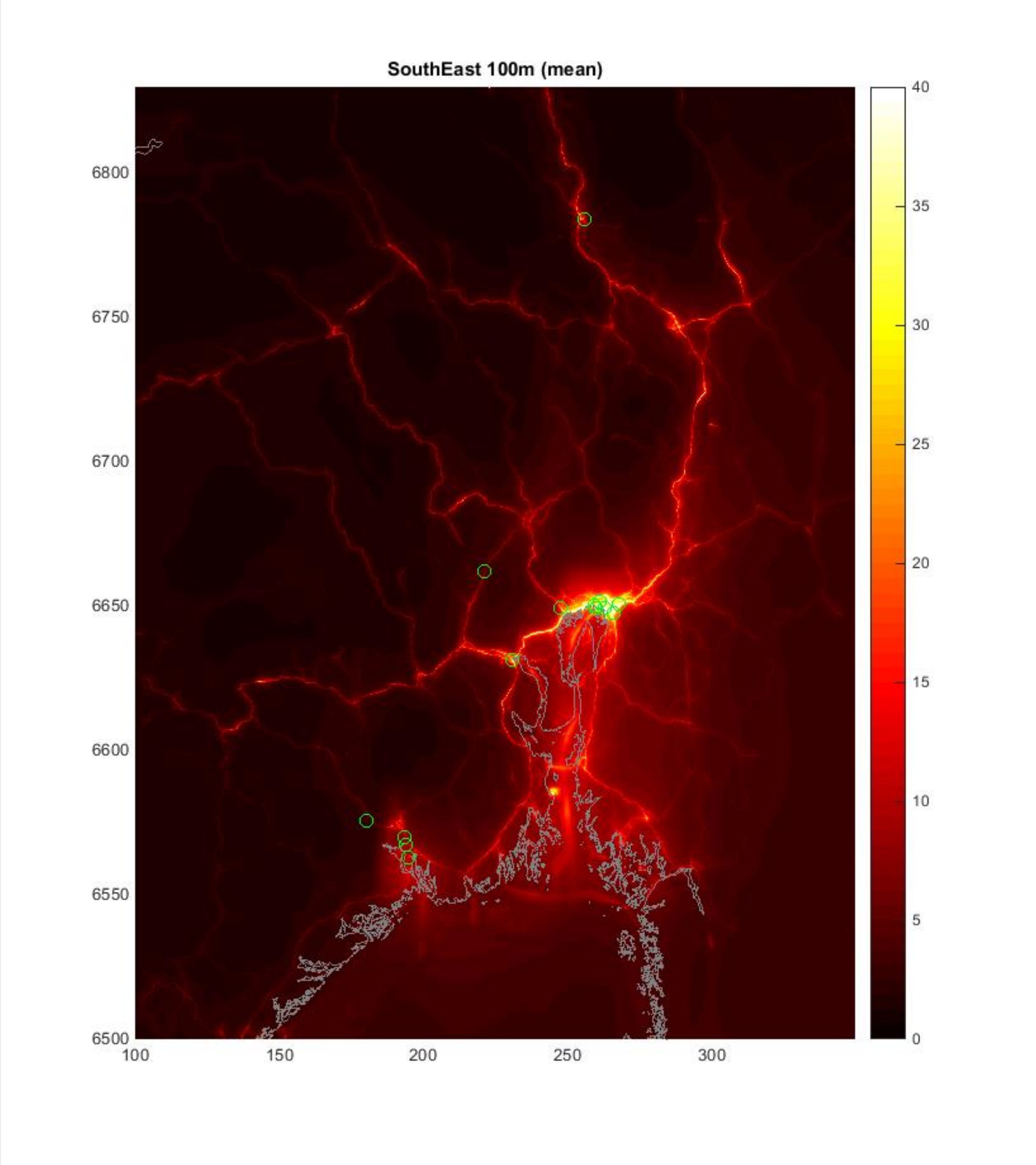
Østlandet NO_2 (2013)



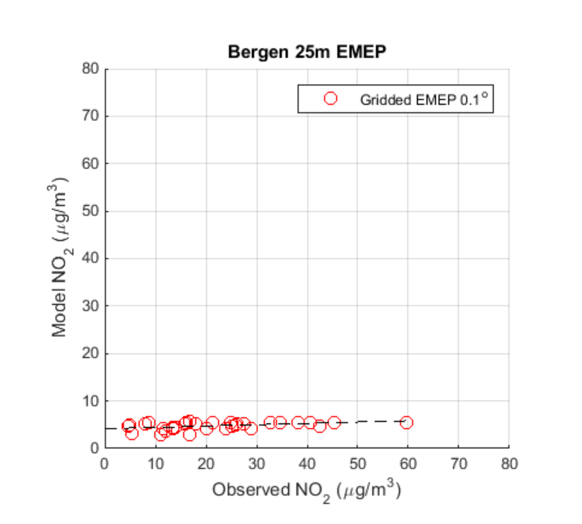
EMEP 0.1° (2013)



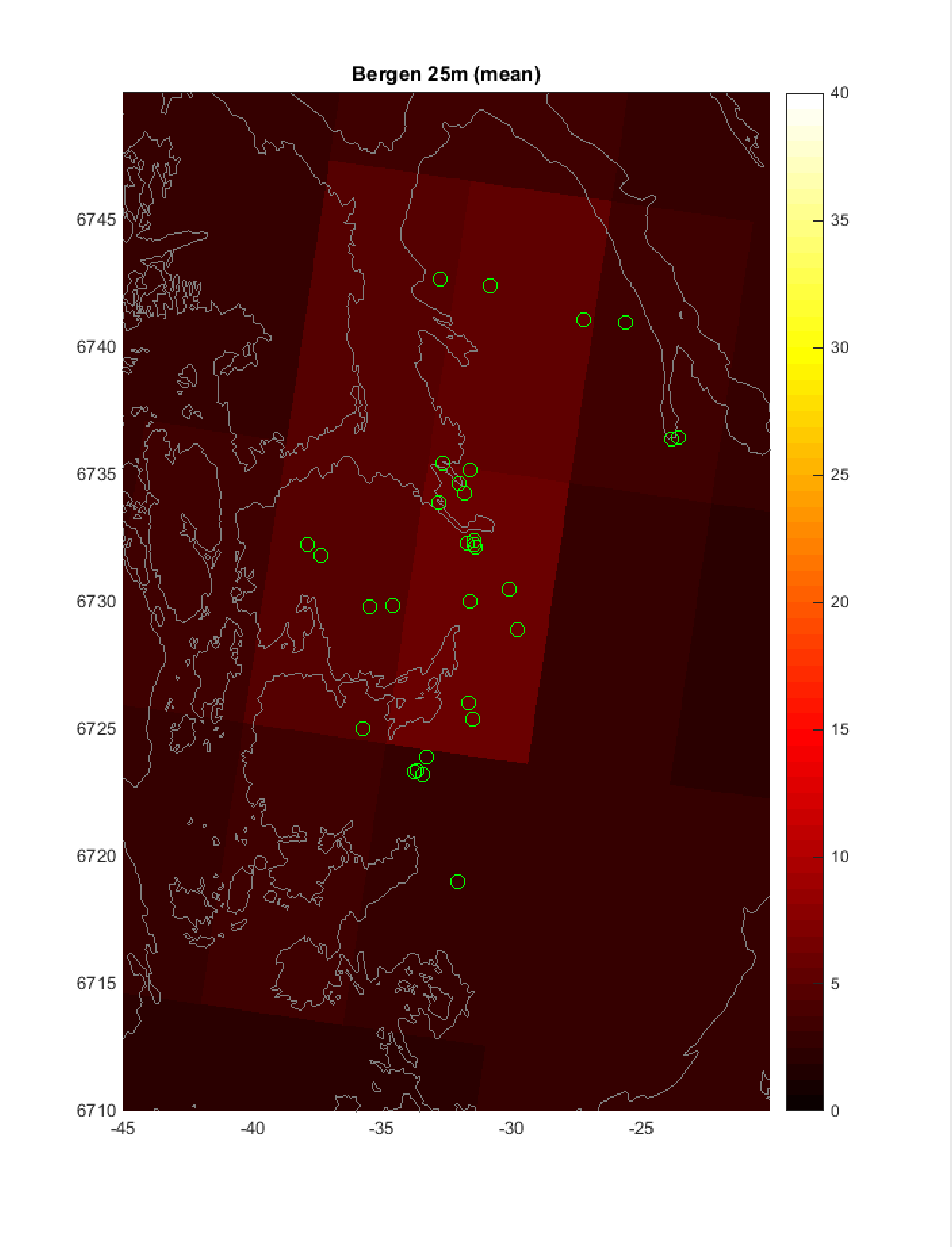
*u*EMEP 100 m (2013)



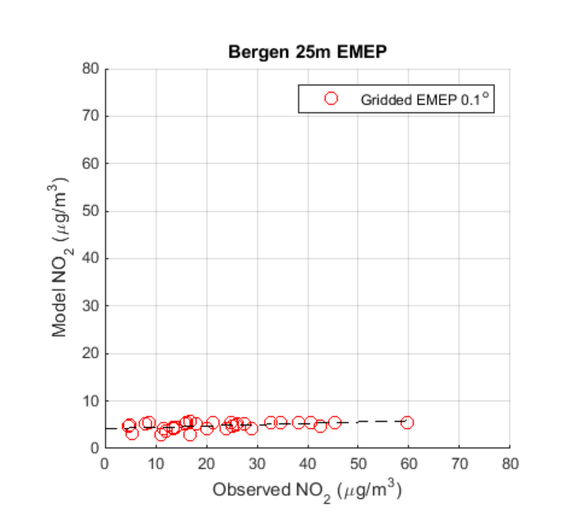
Bergen NO_2 (2013)



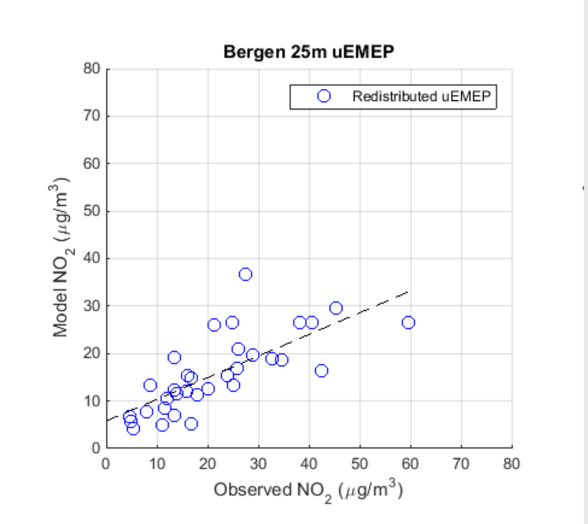
EMEP 0.1° (2013)



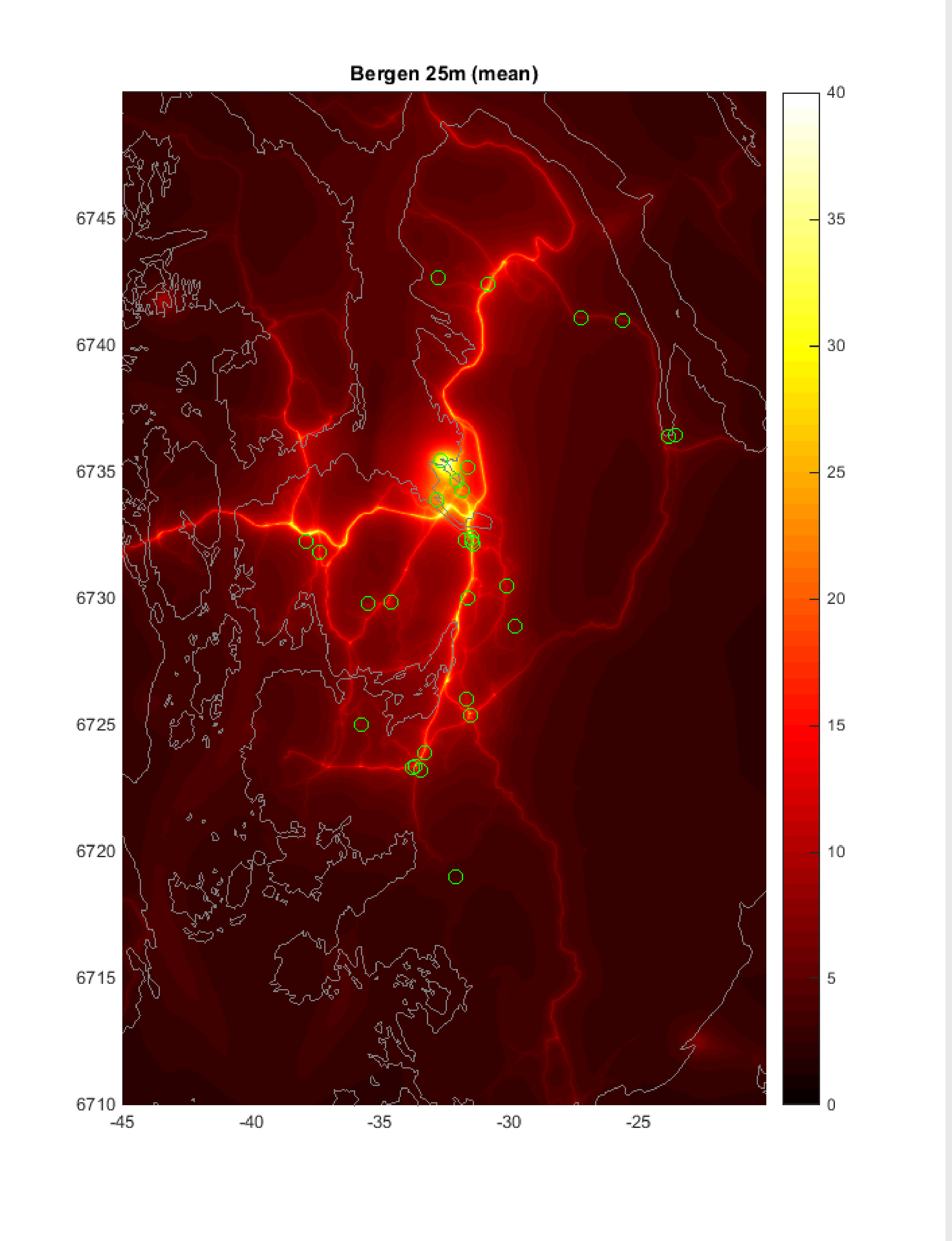
Bergen NO_2 (2013)



EMEP 0.1° (2013)



*u*EMEP 25 m (2013)



Example in The Netherlands

NH_3 annual mean concentration redistributed for agriculture

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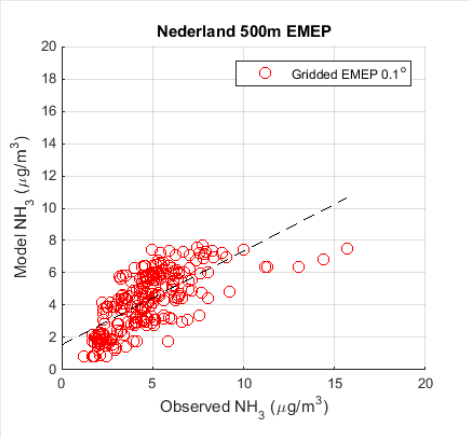
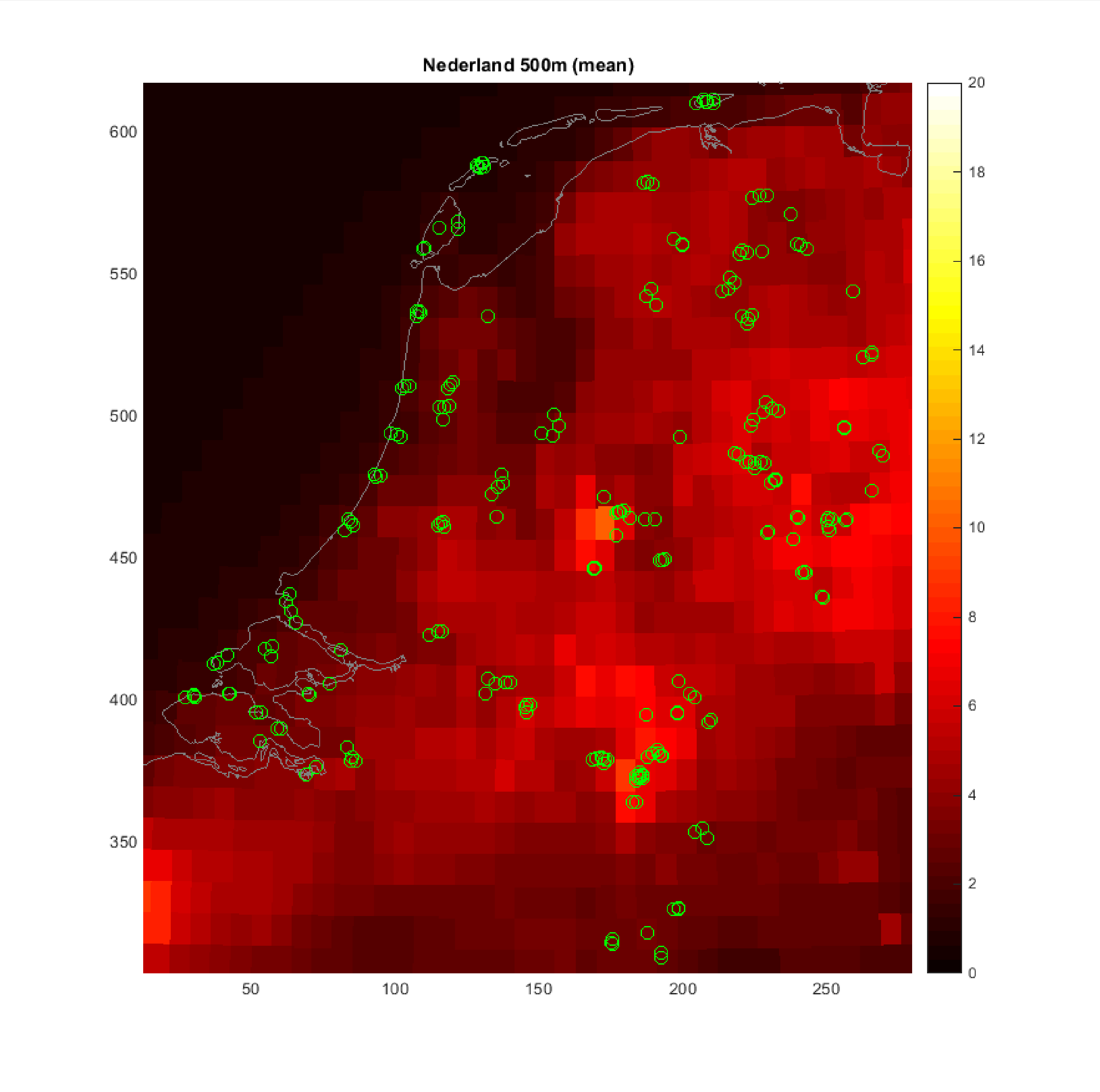
500 m *u*EMEP with RIVM NH_3 emissions in EMEP

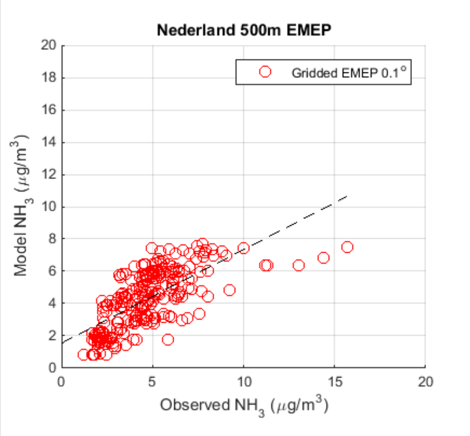
EMEP 0.1°
R^2=0.43



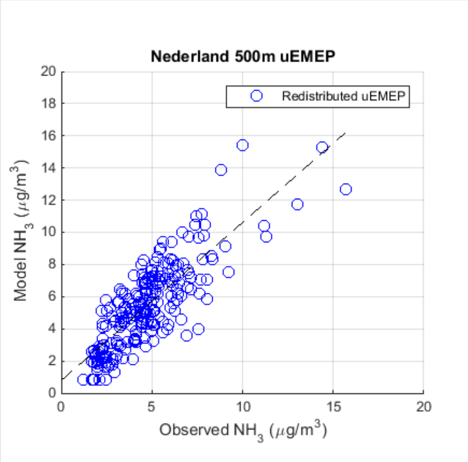


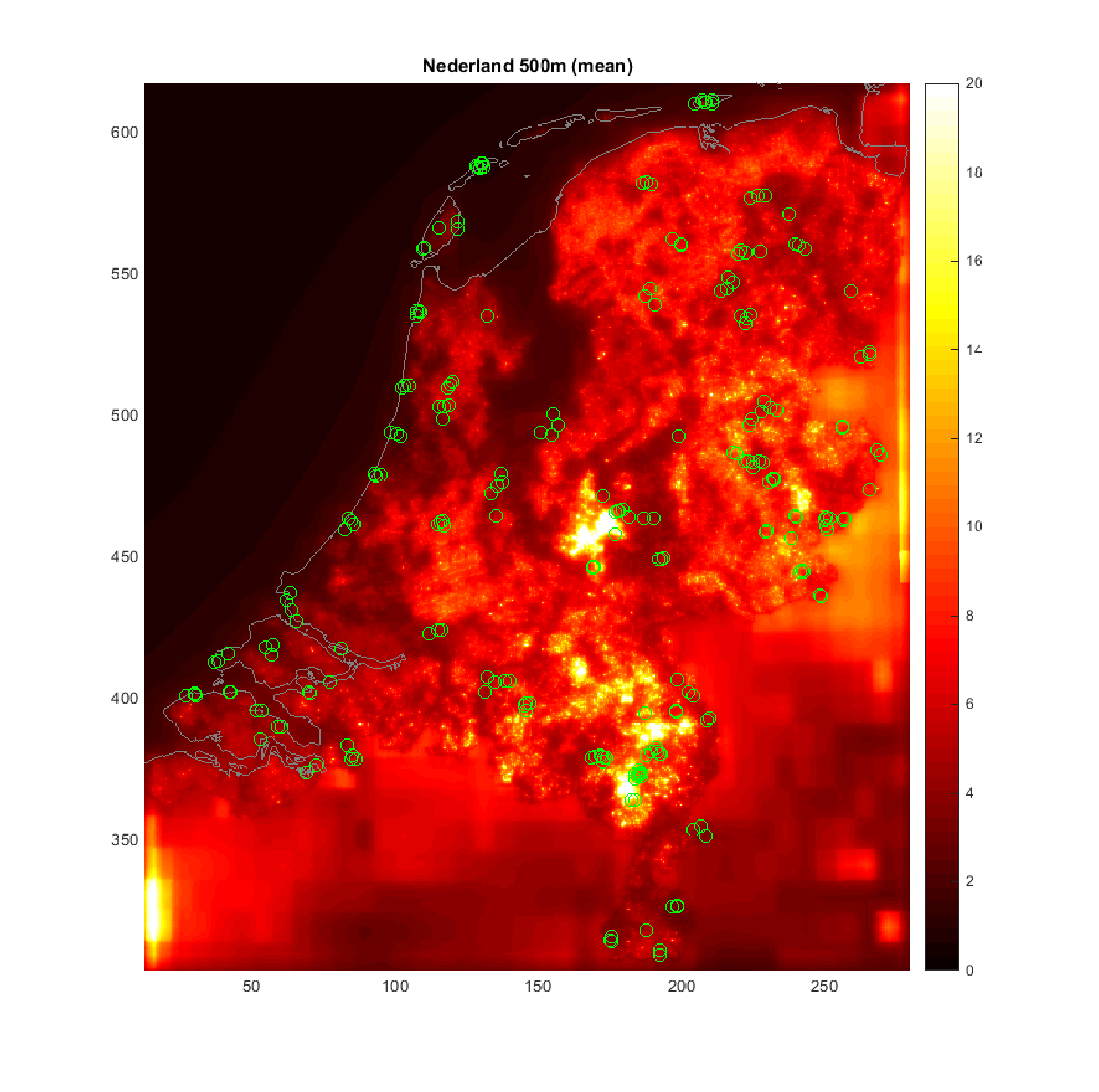
500 m *u*EMEP with RIVM NH_3 emissions in EMEP

EMEP 0.1^o
R^2=0.43

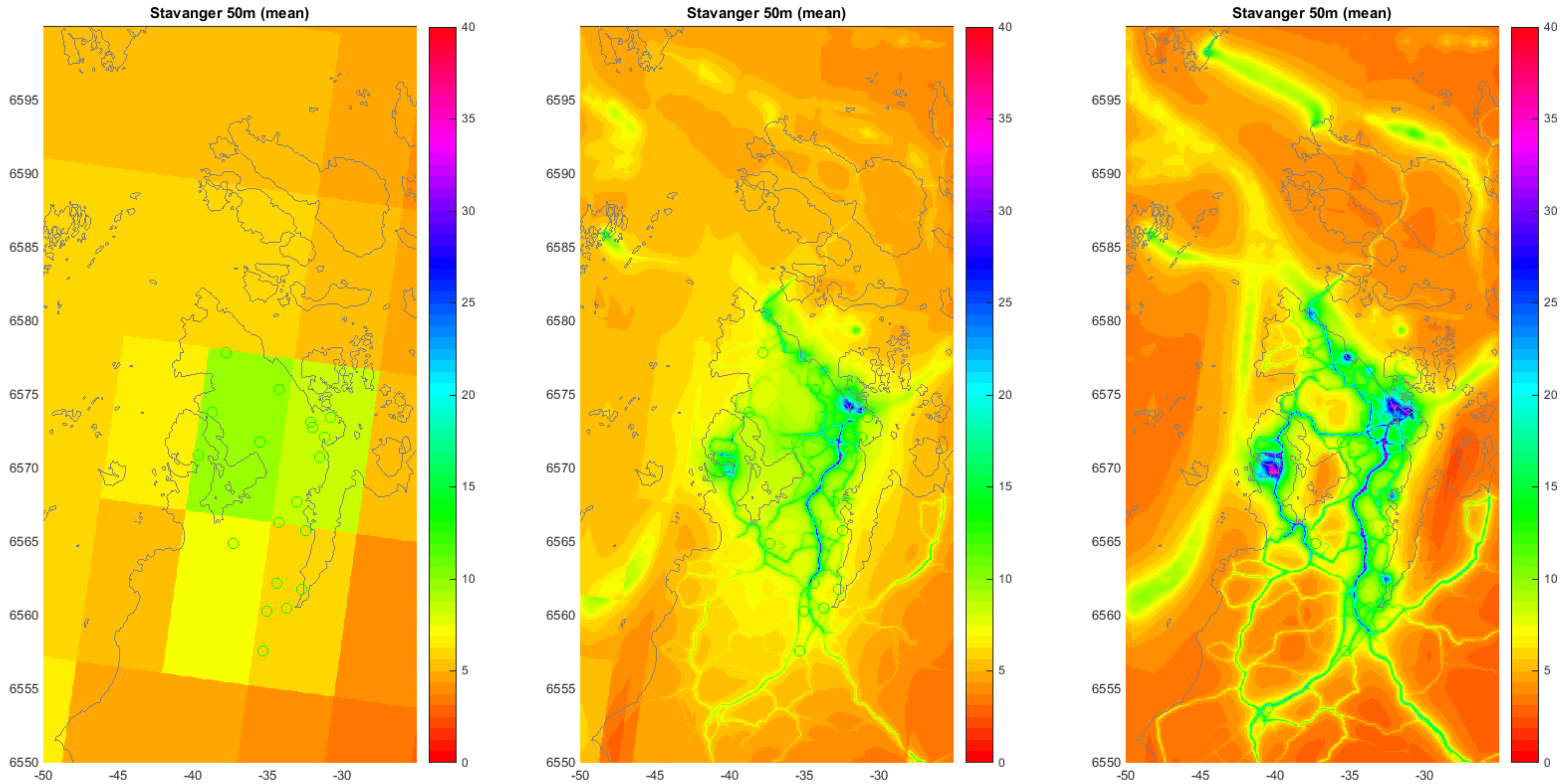


EMEP 0.1^o, *u*EMEP 500 m
R^2=0.67





Stavanger NO_2 (2015)

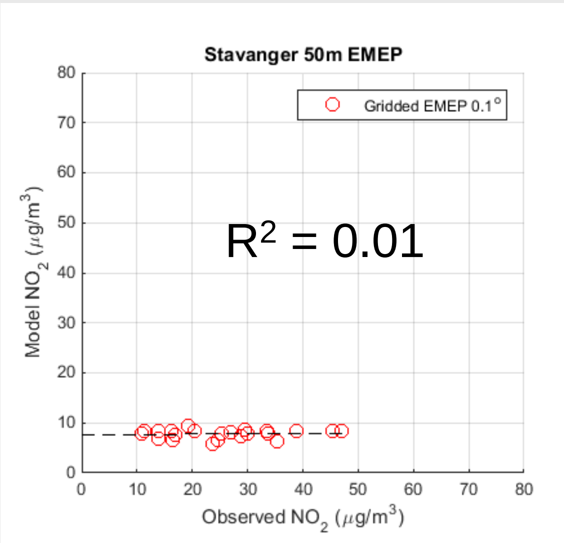


EMEP 0.1° (2015)

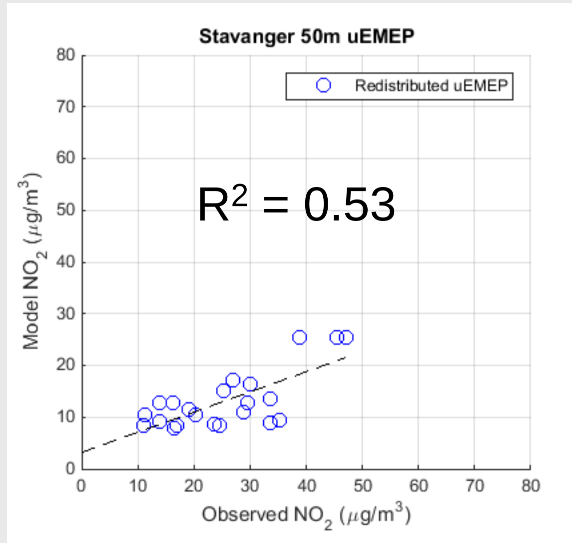
*u*EMEP 50 m Redistributed (2015)

*u*EMEP 50 m Replaced (2015)

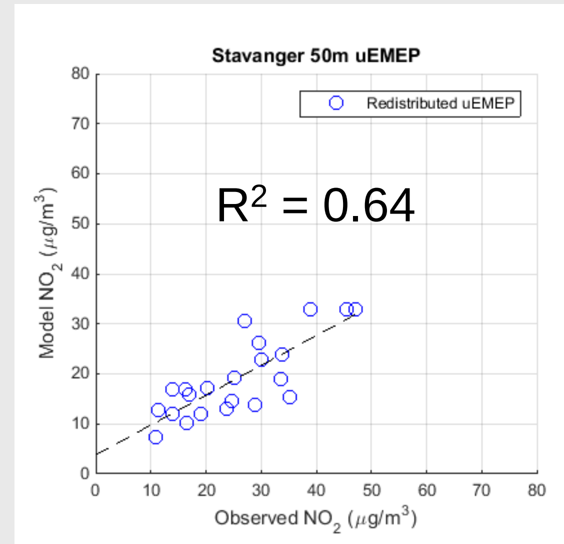
Stavanger NO_2 (2015)



EMEP 0.1° (2015)



*u*EMEP 50 m Redistributed (2015)



*u*EMEP 50 m Replaced (2015)

NOx Emissions used in EMEP underestimated by a factor of 2

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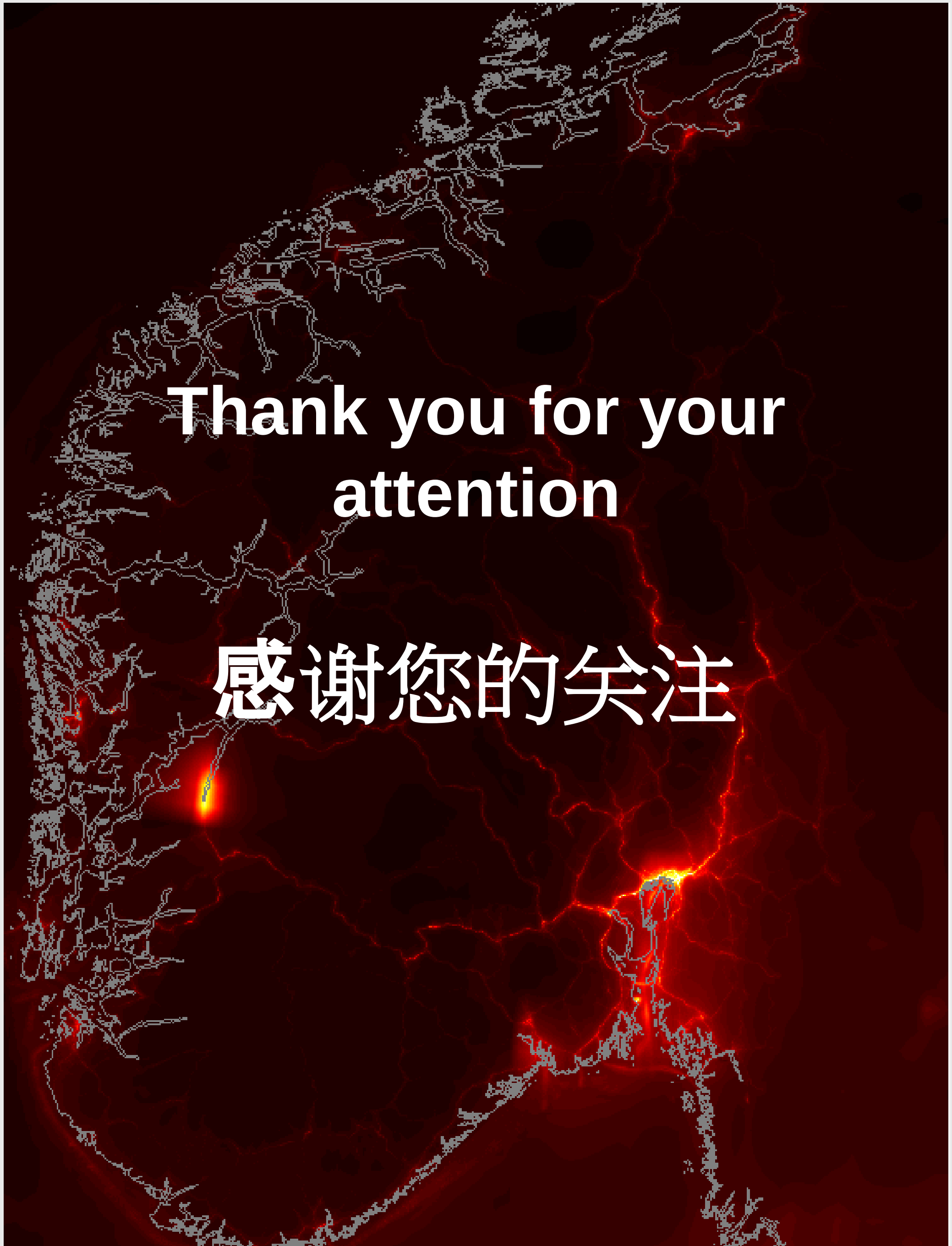
Thank you for your attention

感谢您的关注



Sør Norge årsgjennomsnitt NO_2 konsentrasjon på 250 m oppløsning generert av uEMEP

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*u*EMEP: proxy emission data

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AIRQUIP kickoff meeting 19.04.2017

Proxy emission data

- The high resolution proxy emission data to be used in *u*EMEP is the same sort of data that is used to make bottom up emissions inventories or to disaggregate top down emissions. E.g. direct industrial emissions, road traffic volume, shipping movement data, population density, animal density, etc..

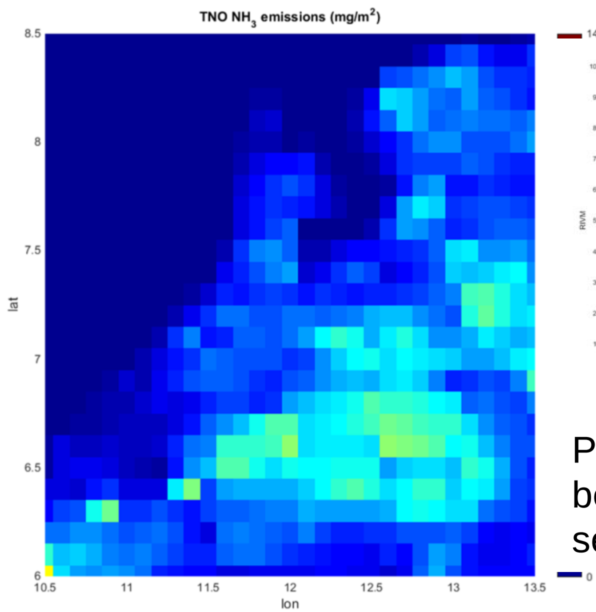
- When applying *u*EMEP as a ‘redistribution’ method then we do not need actual emissions, we only need ‘scalable’ data that represents the relative spatial distribution of the emissions

- The EMEP emission data may not be directly compatible with the proxy emission data. This will be tested as part of the project. The absolute ‘best’ situation is when the same data basis is used for both the proxy emissions and the EMEP emissions

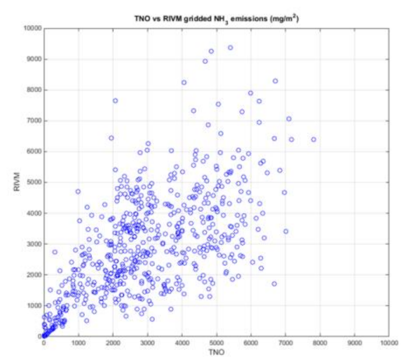
- Currently the best set of data (most complete) we have is for Norway. Data is less complete for Europe and not known yet for China

Example emission data from The Netherlands

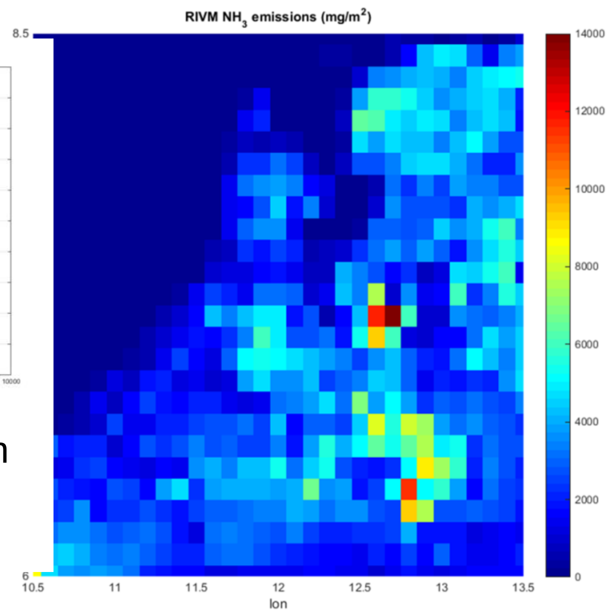
- High quality ammonia emissions are available from RIVM in The Netherlands. Emissions from thousands of individual farm buildings (animal type, number, building type) and 1 km area emissions from fields.
- Comparison between these emissions and EMEPs current emissions from TNO (based on animal density) are not good but the total emissions are the same.



EMEP TNO 0.1º emissions



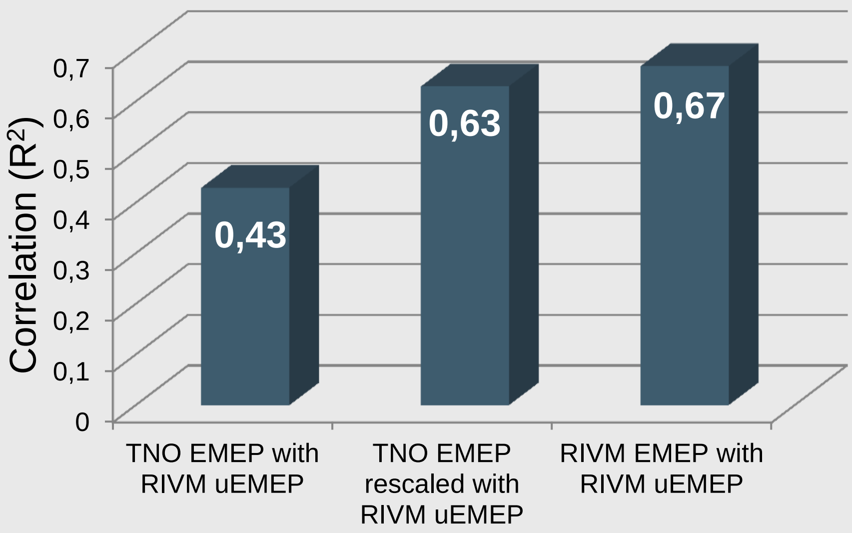
Poor spatial correlation between the two data sets (R^2=0.38)



RIVM detailed emissions

Example emission data from The Netherlands

- How to deal with this typical problem? Two possibilities:
- Rescale the local contribution from EMEP at each grid with the ratio of RIVM/TNO emissions and apply *u*EMEP with RIVM data
- Replace the EMEP TNO emissions with the ‘good’ RIVM emissions directly in EMEP and apply *u*EMEP with RIVM data
- Spatial correlation compared to 250 passive samplers:



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Example traffic proxy emission data from China

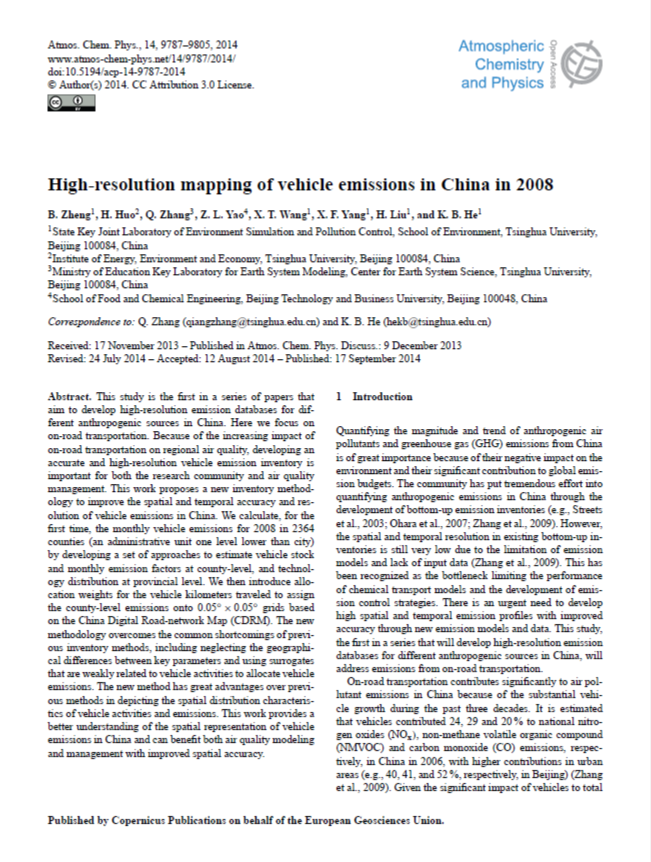
- Zheng, B., Huo, H., Zhang, Q., Yao, Z. L., Wang, X. T., Yang, X. F., Liu, H., and He, K. B.: High-resolution mapping of vehicle emissions in China in 2008, Atmos. Chem. Phys., 14, 9787-9805, doi:10.5194/acp-14-9787-2014, 2014.

- Top down approach where vehicle kilometres are es
  - Total number of vehicles of each type (modelled based or
  - Technology level of vehicles for each type (based on prov
  - Number of kilometres travelled per vehicle type (based o
  - Emission factors per vehicle type and technology (includ

- This is then redistributed in space based on road typ Highways, 8% on County roads, etc.), where the ro China Digital Road-network Map (CDRM)

- Finally this is aggregated to 0.05° grids

- As a starting point for *u*EMEP then the data prior to
- Improvement in the method can come from replacin with satellite counts of vehicles from NR.



Atmos. Chem. Phys., 14, 9787–9805, 2014
www.atmos-chem-phys.net/14/9787/2014/
doi:10.5194/acp-14-9787-2014

High-resolution mapping of vehicle emissions in China in 2008

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[2]Institute of Energy, Environment and Economy, Tsinghua University, Beijing 100084, China
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Abstract. This study is the first in a series of papers that aim to develop high-resolution emission databases for different anthropogenic sources in China. Here we focus on on-road transportation. Because of the increasing impact of on-road transportation on regional air quality, developing an accurate and high-resolution vehicle emission inventory is important for both the research community and air quality management. This work proposes a new inventory methodology to improve the spatial and temporal accuracy and resolution of vehicle emissions in China. We calculate, for the first time, the monthly vehicle emissions for 2008 in 2364 counties (an administrative unit one level lower than city) by developing a set of approaches to estimate vehicle stock and monthly emission factors at county-level, and technology distribution at provincial level. We then introduce allocation weights for the vehicle kilometers traveled to assign the county-level emissions onto 0.05° × 0.05° grids based on the China Digital Road-network Map (CDRM). The new methodology overcomes the common shortcomings of previous inventory methods, including neglecting the geographical differences between key parameters and using surrogates that are weakly related to vehicle activities to allocate vehicle emissions. The new method has great advantages over previous methods in depicting the spatial distribution characteristics of vehicle activities and emissions. This work provides a better understanding of the spatial representation of vehicle emissions in China and can benefit both air quality modeling and management with improved spatial accuracy.

1 Introduction

Quantifying the magnitude and trend of anthropogenic air pollutants and greenhouse gas (GHG) emissions from China is of great importance because of their negative impact on the environment and their significant contribution to global emission budgets. The community has put tremendous effort into quantifying anthropogenic emissions in China through the development of bottom-up emission inventories (e.g., Streets et al., 2003; Ohara et al., 2007; Zhang et al., 2009). However, the spatial and temporal resolution in existing bottom-up inventories is still very low due to the limitation of emission models and lack of input data (Zhang et al., 2009). This has been recognized as the bottleneck limiting the performance of chemical transport models and the development of emission control strategies. There is an urgent need to develop high spatial and temporal emission profiles with improved accuracy through new emission models and data. This study, the first in a series that will develop high-resolution emission databases for different anthropogenic sources in China, will address emissions from on-road transportation.

On-road transportation contributes significantly to air pollutant emissions in China because of the substantial vehicle growth during the past three decades. It is estimated that vehicles contributed 24, 29 and 20 % to national nitrogen oxides (NO_x), non-methane volatile organic compound (NMVOC) and carbon monoxide (CO) emissions, respectively, in China in 2006, with higher contributions in urban areas (e.g., 40, 41, and 52 %, respectively, in Beijing) (Zhang et al., 2009). Given the significant impact of vehicles to total

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Proxy emission data table

Proxy dataset	Representing	Norway	Europe	China ?
Road network data	**Traffic emissions**	NVDB (www.vegdata.no)	Open street map or other routing services	Data from local governments and the Digital Road-network Map (CDRM)
Traffic volume data	**Traffic emissions**	NVDB, satellite imagery for ground truthing and gap filling	Individual national databases, satellite imagery, TREMOVE scenarios for major roads.	Estimates from emission inventories, satellite imagery
Satellite imagery for traffic volume data	**Traffic emissions**	Google Earth	Google Earth	-
Shipping position and emission data	**Shipping emissions**	AIS data, available from kystverket, www.havbase.no	AIS data and national databases	-
Industrial site positions and emissions	**Industrial emissions**	Available from the Norw. Environment Agency (www.norskeutslipp.no)	Available from EPRTR (prtr.ec.europa.eu)	For Beijing and Guangzhou (local environm. agencies)
Population and dwelling density	**Domestic heating emissions**	Available from SSB at 250 m resolution for all of Norway (www.ssb.no/natur-og-miljo/geodata) or home addresses from kartverket	Available from EEA (www.eea.europa.eu/data-and-maps/data/population-density-disaggregated-with-corine-land-cover-2000-2)	1x1 km resolution from LANDSCAN
Topographical data	**For pseudo dispersion modelling**	Available for all of Norway at 10 - 50m (data.kartverket.no)	Available from EEA at 30 m, (www.eea.europa.eu/data-and-maps/data/eu-dem)	-
Building positions	**For pseudo dispersion modelling**	Available for all of Norway at municipality level on shp format (shapefiles at 'norge digitalt', www.geonorge.no/)	Unknown	To be decided during the project.
Improved temporal emission data	**For EMEP calculations**	Not applicable	Not applicable	Data from Tsinghua Research group

Proxy emission data availability in China

- What relevant data is available and to whom is it available?
- How related are these data to the actual emissions used in EMEP modelling in China?
- What form/format are these data in?
- To what extent can new data be gathered?
- How do we best make use of traffic data gathered by satellite and integrate it into the datasets?
- Delegation of roles
- Plan for gathering and applying these data

Additional slides

*u*EMEP: concept and application

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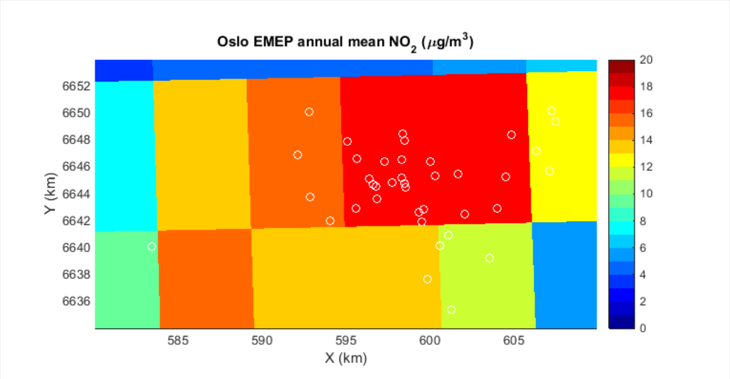
How does *u*EMEP work? Local source contribution

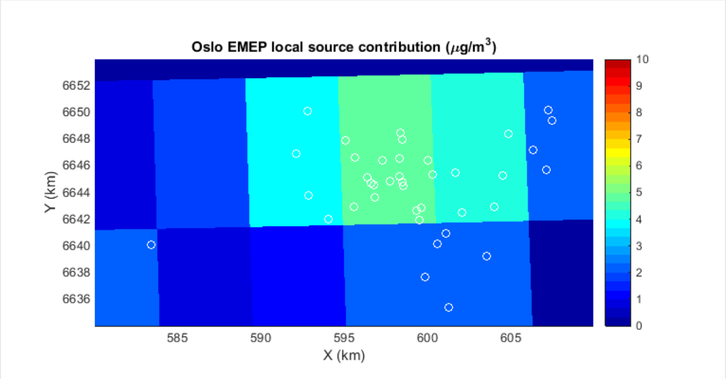
*u*EMEP consists of several elements that can be applied in different ways to downscale EMEP grid concentrations to target sub-grid concentrations. The following 3 elements can be used in different ways

1. EMEP calculates and tracks the **source contribution** in each EMEP grid *(I,J)*, as well as the surrounding grids. It does this for every calculation time step. This provides an hourly or an annual **local source contribution** in each EMEP grid

$$C_{EMEP}(I,J) = C_{local}(I,J) + C_{nonlocal}(I,J)$$



EMEP total grid concentration



EMEP local traffic source contribution

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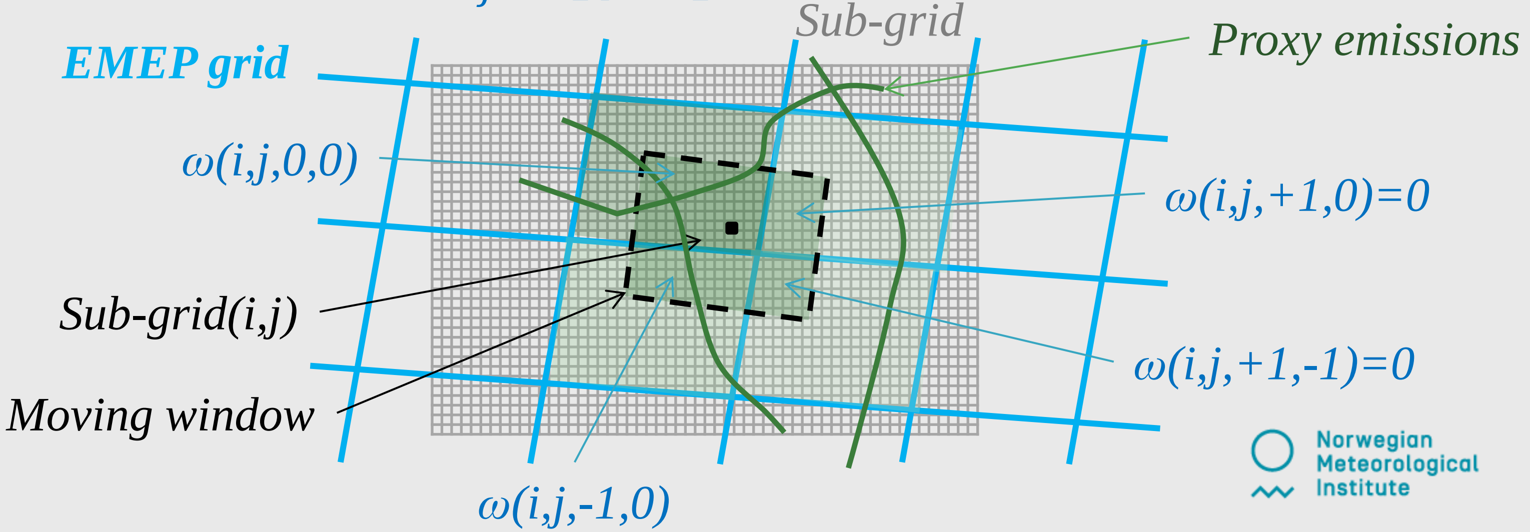
How does *u*EMEP work? Moving window

2. A **moving window** method is used to deal with 'edge effects' created near EMEP grid boundaries. This method simulates a repositioning of the EMEP grid centred on the sub-grid point that is being calculated. A weighted interpolation (ω), based on emission distribution, of the EMEP **local source contribution** at each sub-grid point *(i,j)* is made

$$C_{EMEP}(i,j,I,J) = \sum_{J'=-1}^{+1} \sum_{I'=-1}^{+1} C_{local}(I+I',J+J') \cdot \omega(i,j,I',J')$$



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How does *u*EMEP work? Sub-grid dispersion

3. Proxy (or real) emission data, *e(i,j)*, are ‘dispersed’ using standard Gaussian methods (f_{Gauss}) within the EMEP grid area, either on an hourly or an annual basis, to each sub-grid. The **dispersed proxy emissions** are calculated at the surface and also integrated over the lowest EMEP grid to determine the grid average volume

$$c_{proxy}(I,J,i,j,z) = \sum_{j'=-n/2}^{+n/2} \sum_{j'=-n/2}^{+n/2} f_{Gauss}(i,j,i',j') \cdot e(i',j')$$

$$c_{volume-proxy}(I,J,i,j) = \frac{1}{n^2} \sum_{j'=-n/2}^{+n/2} \sum_{j'=-n/2}^{+n/2} \frac{1}{H} \int_0^H c_{proxy}(I,J,i,j,z)\, dz$$

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How does *u*EMEP work? Sub-grid concentrations

The following methods can be used to determine the sub-grid concentrations

1. **Redistribute** the local EMEP grid source contribution and replace it with the sub-grid concentration

$$c_{subgrid}(i,j,I,J,z) = C_{EMEP}(i,j,I,J) \cdot \frac{c_{proxy}(I,J,i,j,z)}{c_{volume-proxy}(I,J,i,j)} + C_{nonlocal}(I,J,i,j)$$

2. If the proxy data is real bottom up emission data then remove the local EMEP grid source contribution and **replace** it with the independent Gaussian calculation

$$c_{subgrid}(i,j,I,J,z) = c_{proxy}(I,J,i,j,z) + C_{nonlocal}(I,J,i,j)$$

3. Alternatively EMEP emissions can be redistributed over the proxy emission sub-grid data and method 2 applied
4. The local EMEP grid source contribution can be rescaled to represent differences in bottom up and top down emission inventories or to represent scenario calculations

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What do we learn from these different approaches?

- Method 1 (Redistribution) makes use of the regional scale emission data and allows a direct comparison of regional scale concentrations with urban monitoring data. Results are dependent on EMEP dispersion and advection as well as emissions. **Redistribution does not change the average grid volume concentration**.

- Method 2 (Replacement) adjusts for double counting of emissions and allows any dispersion model or emission inventory to be used to recalculate the sub-grid concentrations. **Replacement will change the average grid volume concentration but gives more flexibility**.

- Comparison of 1 and 2 allows an assessment of the dispersion characteristics of the two methods and comparison of emissions

- By using method 3 an assessment of the different emissions can be made and a direct comparison made with observed concentrations.

Some other points

- We want the sub-grid and EMEP dispersion physics to be compatible and harmonised. Make use of EMEP's vertical diffusion coefficient (K_z) in the Gaussian dispersion. Where these differ we need to assess the impact and if necessary re-evaluate EMEP dispersion.
- We want the sub-grid proxy emission data to reflect the EMEP emission data. Ideally an aggregated sub-grid emission field would be the same as an EMEP emission field.
- The EMEP local source contribution scheme can be extended to cover any defined area, allowing 'internal' and 'external' contributions for a city to be better defined

Status?

- The local source contribution calculation in EMEP is well developed
- Significant amount of Fortran code written for the *u*EMEP post-processing
- Have to date mostly looked at post-processing of annual means for NO_x and NO_2 in Norway

- *u*EMEP is still underdevelopment and many points still need to be explored and assessed. These include:
  - Most suitable Gaussian dispersion methodology
  - Compatibility of the Eulerian and Gaussian dispersion methodologies
  - Non-linear chemistry
  - Application to deposition
  - Optimisation of the method and code
  - Implementation operationally

- We are involving other European colleagues (Nederland, Scotland) in order to build up datasets for testing

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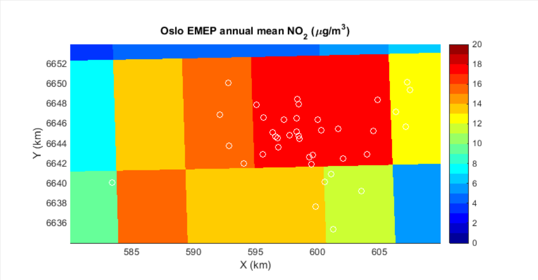
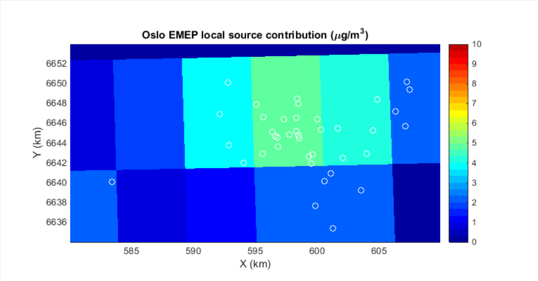
Short summary of the *u*EMEP redistribution method

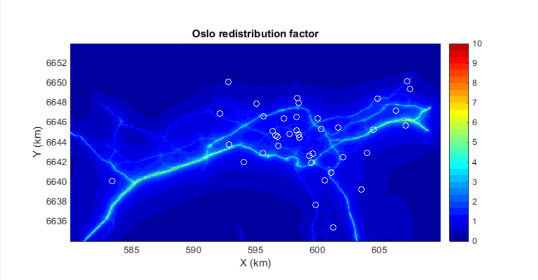
Start with EMEP grid concentrations



Determine the local source contribution in each grid within the EMEP model



Off line routine disperses proxy emission data using Gaussian methods



Off line routine redistributes the EMEP local source contribution using the dispersion proxy to the sub-grid and then adds the non-local EMEP grid concentration