



# Modelling activities in the Danish air quality monitoring program

Camilla Geels, Lise M. Frohn,  
Jørgen Brandt, Jesper H.  
Christensen, Matthias Ketzel,  
Steen Solvang Jensen, Ulas Im,  
Per Løfstrøm, Anne Sofie Lansø,  
and Thomas Ellermann.

Part of DCE and funded by the  
Danish Ministry of the  
Environment and Food.





# The Danish monitoring program:

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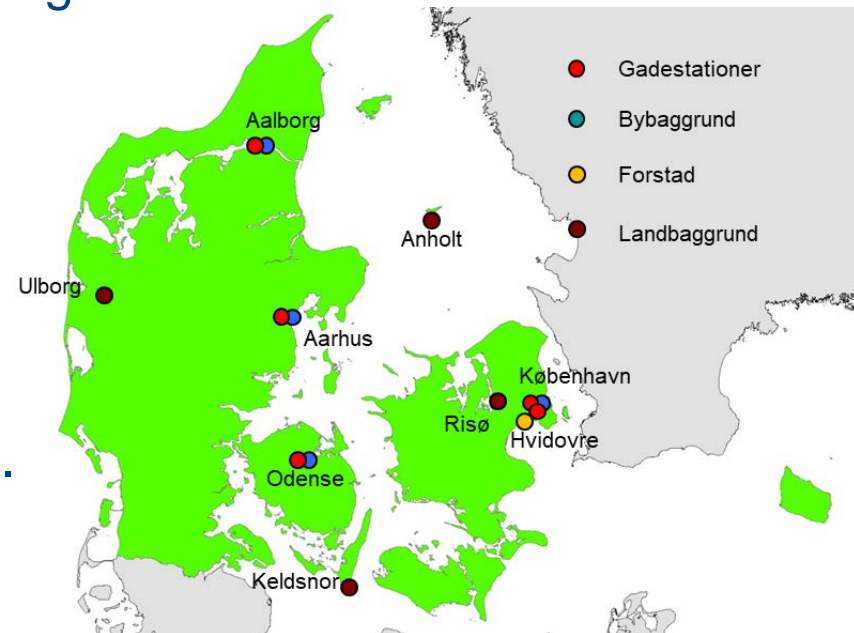
- › **Covers all of Denmark (special focus on main cities). With the aim of:**
- › Reporting the current levels in relation to EU's air quality limit/target values.
- › Reporting under international conventions e.g. EMEP.
- › Investigating the long term trends and to evaluate the impact of Danish and international measures.
- › Warn the Danish public, when EU's warning thresholds are exceeded ( $O_3$ ).
- › Estimate the health effects and external costs of air pollution in Denmark ('new feature').





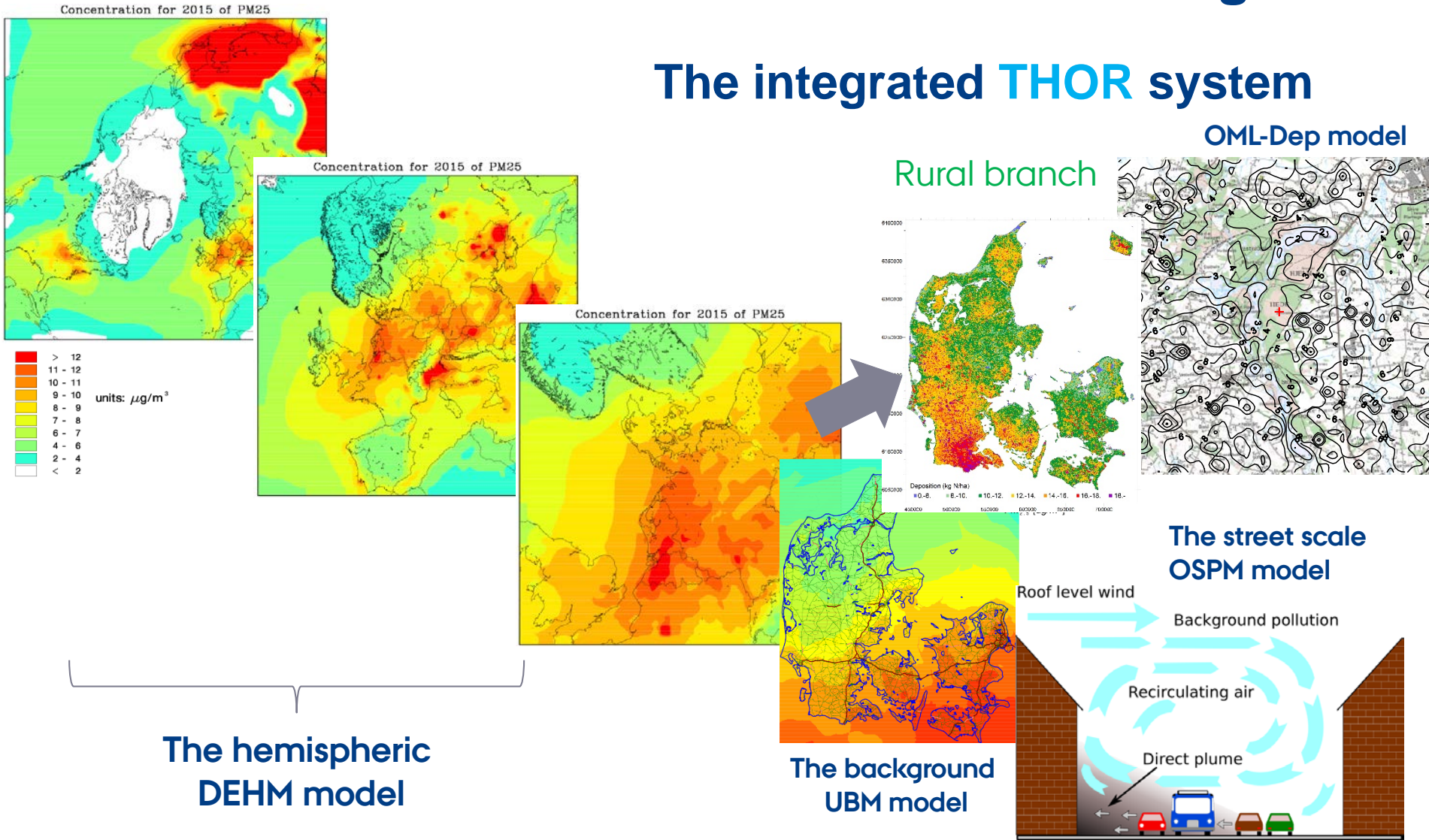
# The Danish monitoring program:

- › Based on an **integration** of measurements and model calculations.
- › The measurements are carried out at 18 monitoring stations.
- › The model calculations are carried out using our multiscale model system.
- › Health assessment is based on the EVA system, also developed in our group.
- › Continuously developed in research projects -> sciences based advisory work.



# Multiscale modelling:

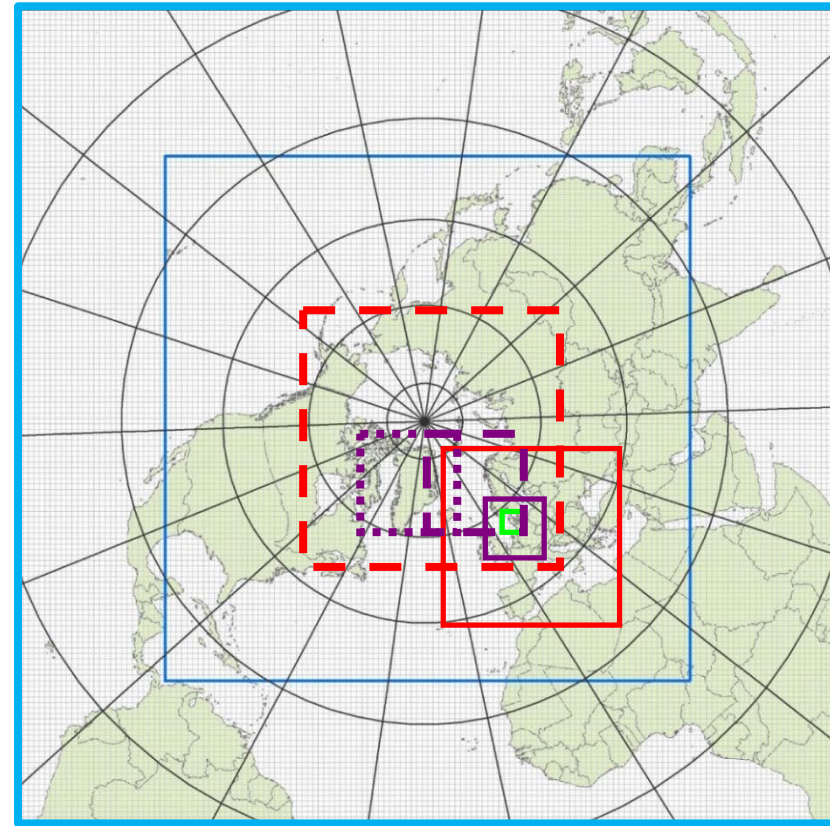
## The integrated THOR system



All models are developed here.

# The Danish Eulerian Hemispheric Model (DEHM)

- > **Chemistry: photo-chemistry (73 species) and particles (9 species)**  
+ POPs, mercury, pollen, CO<sub>2</sub>, UFP etc.
- > Anthropogenic and natural emissions.
- > Emission tagging capability.
- > Flexible setup:
  - Two-way nesting.
  - Met. input from WRF/IFS/climate models.
- > Data Assimilation (OI, 3D-var).
- > Part of CAMS50/CAMS2\_40



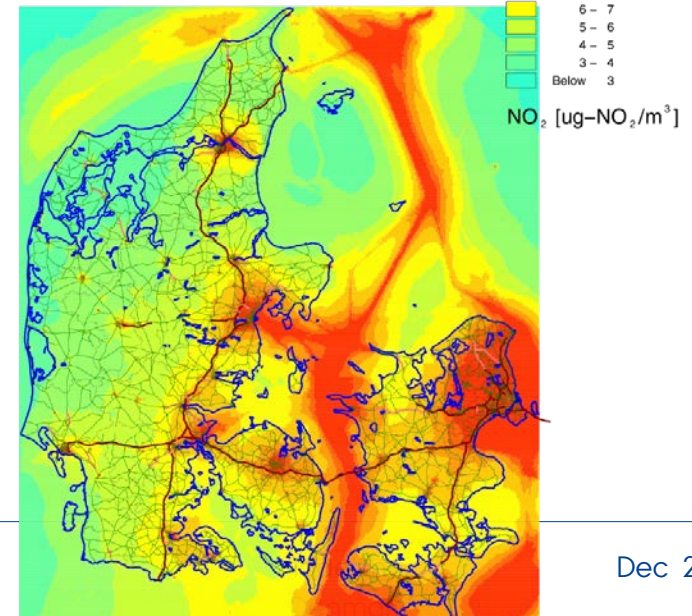
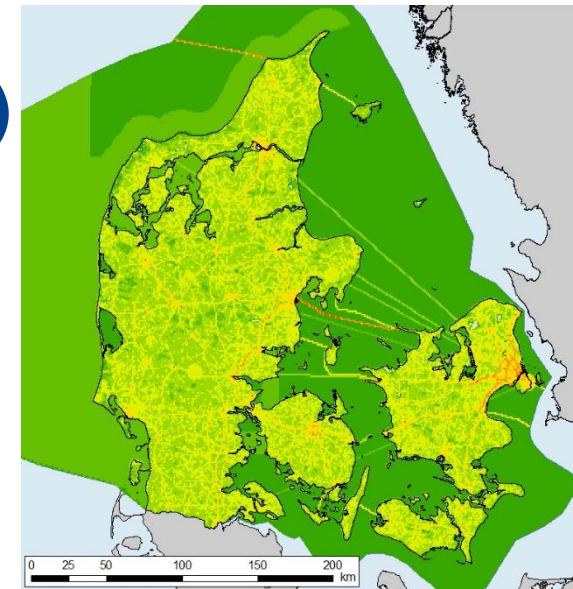
Resolution 150 km -> 5.6 km



# The Urban Background Model (UBM)

- > Gaussian multiple plume model.
- > Resolution 1 km x 1 km.
- > Hourly input (meteorology, regional air pollution) from DEHM-WRF.
- > Emissions based on the SPREAD model.
- > Simplified chemistry/physics.
- > Output: Hourly values of O<sub>3</sub>, NO, NO<sub>2</sub>, NO<sub>x</sub>, CO and PM.
- > Phd student working on a new version.

NO<sub>x</sub> emissions



# Operational Street Pollution Model -OSPM®

- Parameterized model - based on physics:

- Direct plume

- Traffic produced turbulence

- Recirculation

- GIS data on e.g.:

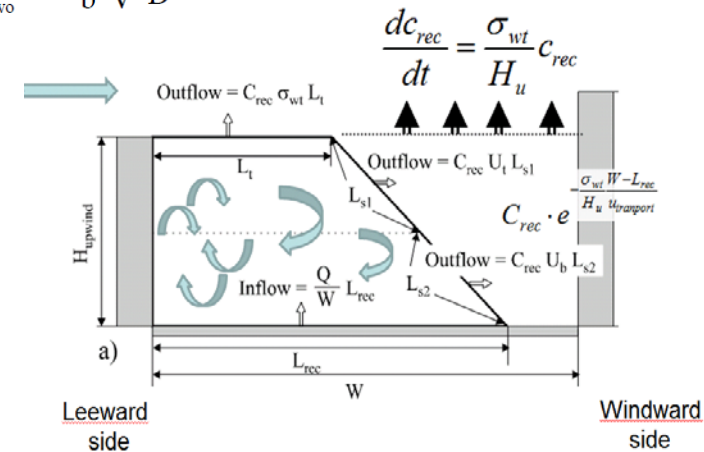
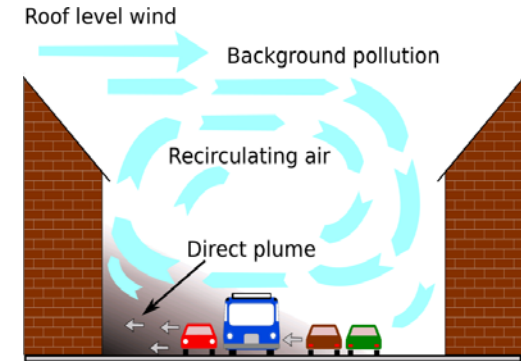
- Building/street configurations

-Traffic emissions

$$\sigma_z(x) = \sigma_w \frac{x}{u_b} + h_0$$

$$\sigma_w = \left( (\alpha u_b)^2 + \sigma_{wo}^2 \right)^{1/2}$$

$$\sigma_{wo}^2 = b^2 V^2 D$$



Atmospheric Environment  
Volume 198, 1 February 2019, Pages 102-121



Development and performance evaluation of new AirGIS – A GIS based air pollution and human exposure modelling system

Jibran Khan <sup>a, b</sup>, Konstantinos Kakosimos <sup>b</sup>, Ole Raaschou-Nielsen <sup>a, c</sup>, Jørgen Brandt <sup>a</sup>, Steen Solvang Jensen <sup>a</sup>, Thomas Ellermann <sup>a</sup>, Matthias Ketzler <sup>a, d, e</sup>

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<https://doi.org/10.1016/j.atmosenv.2018.10.036>

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Modelling  
Denmark

Dec 2021

7

# Pt. number/UFP introduced first attempt (not reported)

Atmospheric Environment 264 (2021)

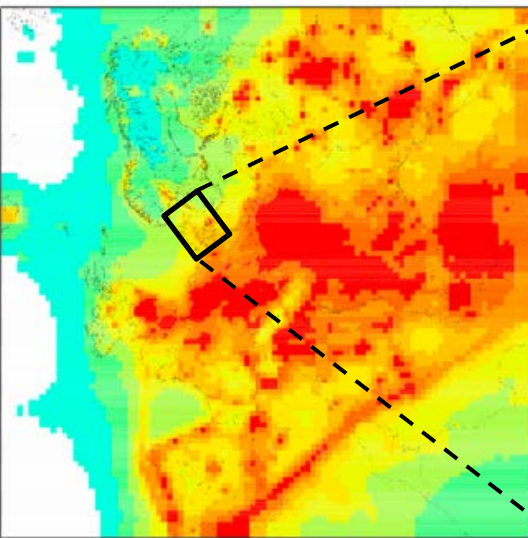
Modelling ultrafine particle number concentrations at address resolution in Denmark from 1979-2018 – Part 1: Regional and urban scale modelling and evaluation

Lise Marie Frohn <sup>a, R, B</sup>, Matthias Ketzel <sup>a, d</sup>, Jesper Heile Christensen <sup>a</sup>, Jørgen Brandt <sup>a, e</sup>, Ulas Im <sup>a, e</sup>, Andreas Massling <sup>a, e</sup>, Christopher Andersen <sup>a, f</sup>, Marlene Schmidt Plejdrup <sup>a</sup>, Ole-Kenneth Nielsen <sup>a</sup>, Hugo Denier van der Gon <sup>b</sup>, Astrid Manders-Groot <sup>b</sup>, Ole Raaschou-Nielsen <sup>a, c</sup>

Modelling ultrafine particle number concentrations at address resolution in Denmark from 1979 to 2018 - Part 2: Local and street scale modelling and evaluation

Matthias Ketzel <sup>a, c, R, B</sup>, Lise M. Frohn <sup>a</sup>, Jesper H. Christensen <sup>a</sup>, Jørgen Brandt <sup>a, e</sup>, Andreas Massling <sup>a</sup>, Christopher Andersen <sup>a, f</sup>, Ulas Im <sup>a</sup>, Steen Solvang Jensen <sup>a</sup>, Jibril Khan <sup>a, f</sup>, Ole-Kenneth Nielsen <sup>a</sup>, Marlene S. Plejdrup <sup>a</sup>, Astrid Manders <sup>b</sup>, Hugo Denier van der Gon <sup>b</sup>, Prashant Kumar <sup>c</sup>, Ole Raaschou-Nielsen <sup>d, a</sup>

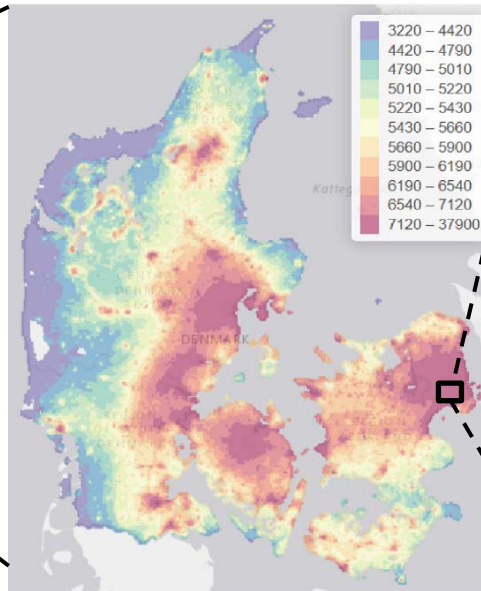
DEHM - regional



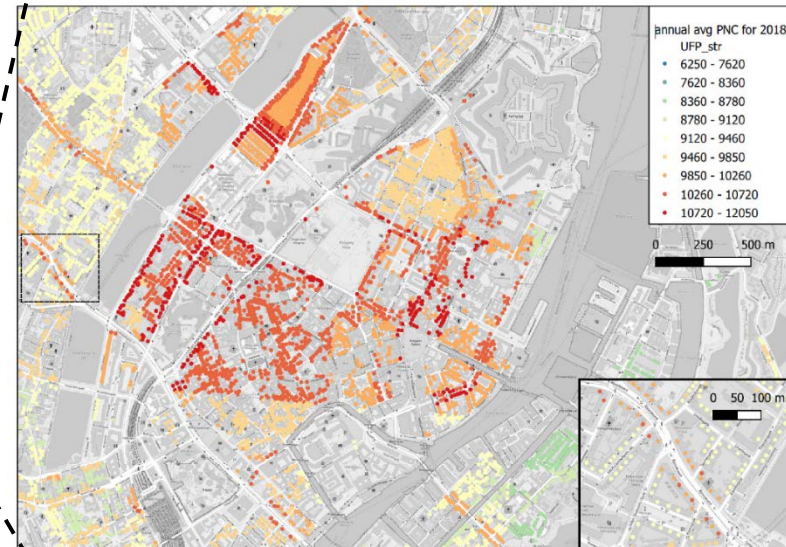
Annual average 2018

Particle number concentration in # / cm3

UBM - local



OSPM - street



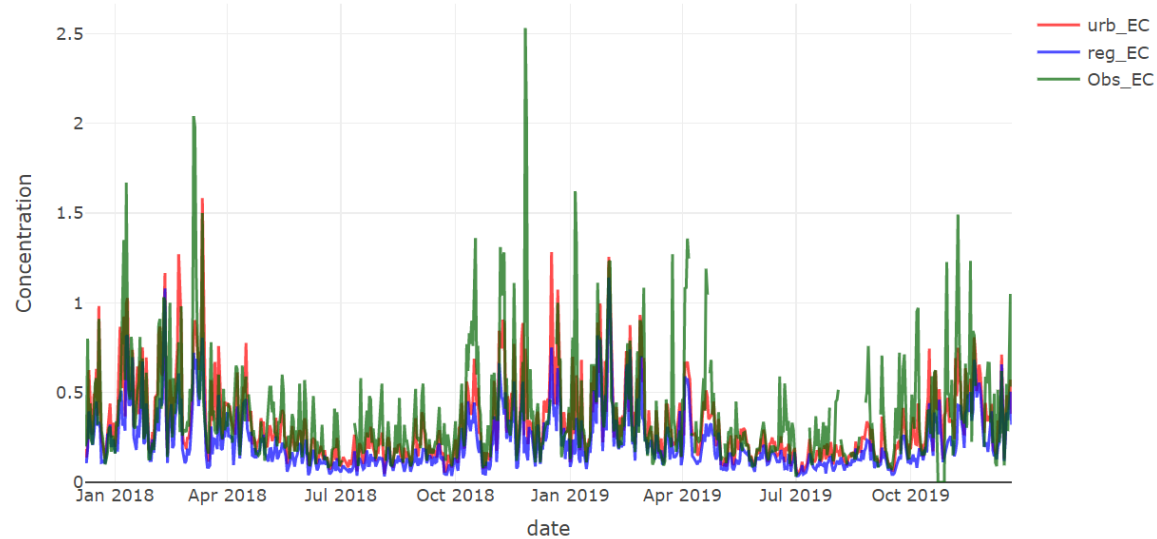
Modelling  
Denmark

Dec 2021

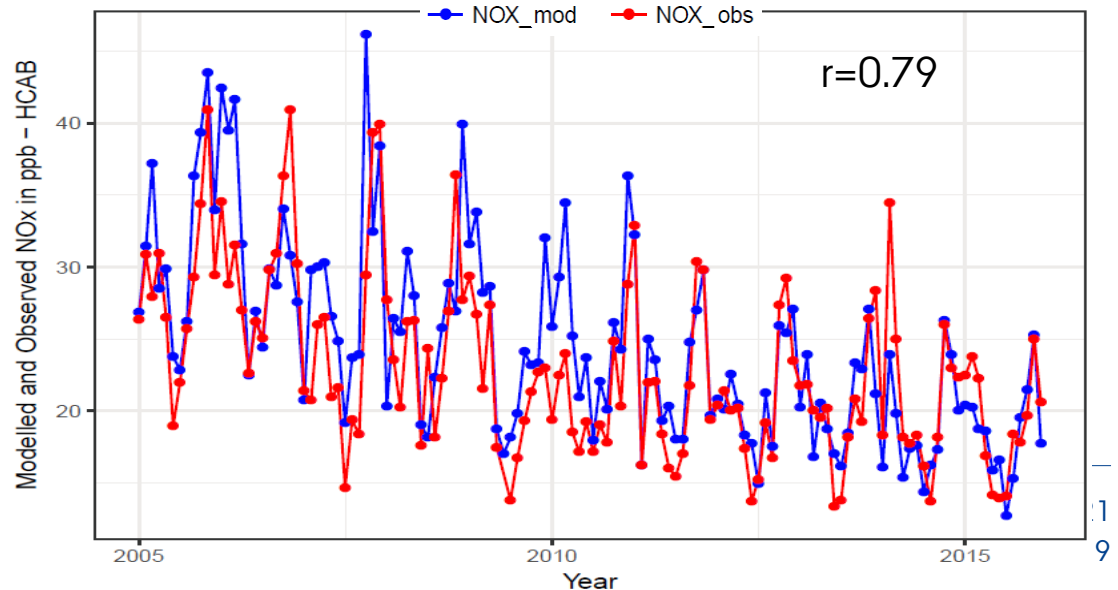
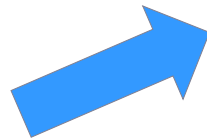


# Example from the evaluation

› EC in Hvidovre (small-scale wood combustion): daily variability captured by **DEHM-UBM**.

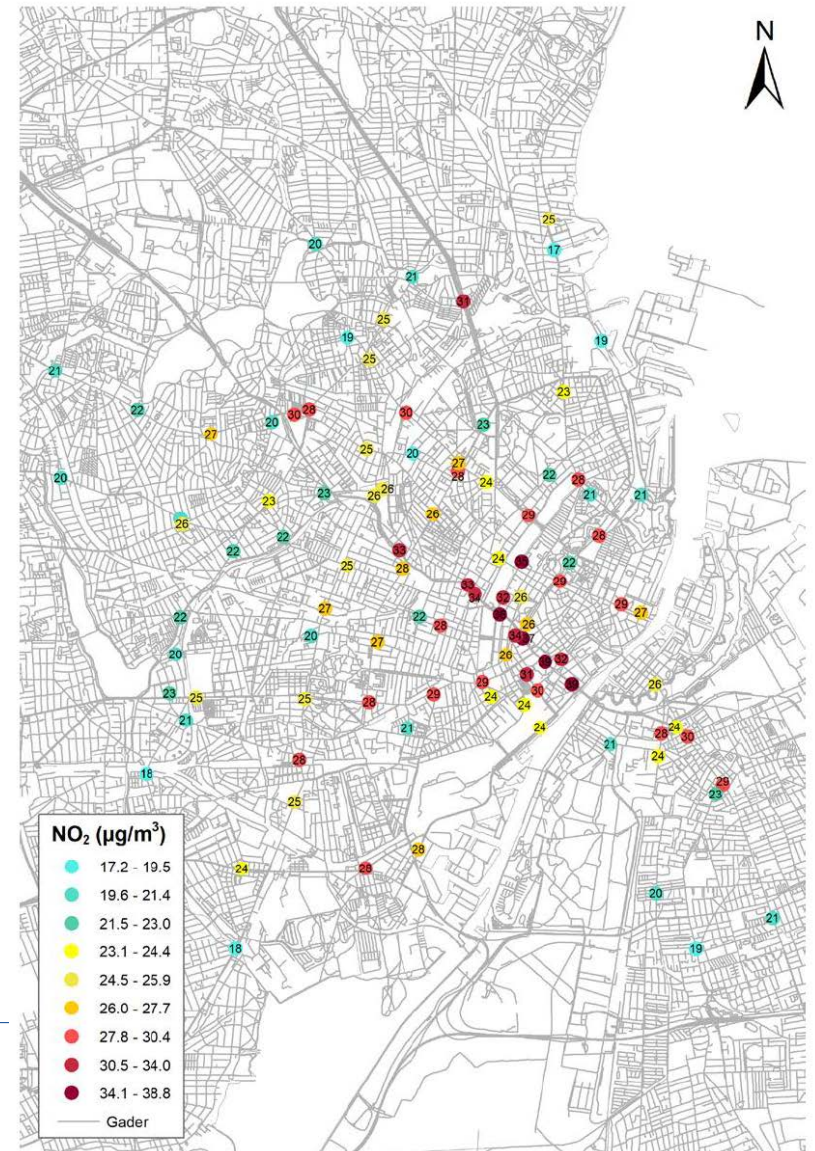


› Monthly mean NO<sub>x</sub> at a street site in KBH (HCAB) capture by **OSPM**.



# Street NO<sub>2</sub> concentration in Copenhagen

- › OSPM is run for selected streets in Aalborg and Copenhagen.
- › To evaluate the levels in relation to EU's limit value (40  $\mu\text{g}/\text{m}^3$ ).
- › No exceedances the last few years.
- › Interactive web-page to access AQ information at street level for all addresses in Denmark  
[Luftenpaadinvej.au.dk](http://Luftenpaadinvej.au.dk)



# Assessment of health impacts and costs:

> Now included in the reporting:

Estimated # premature deaths:

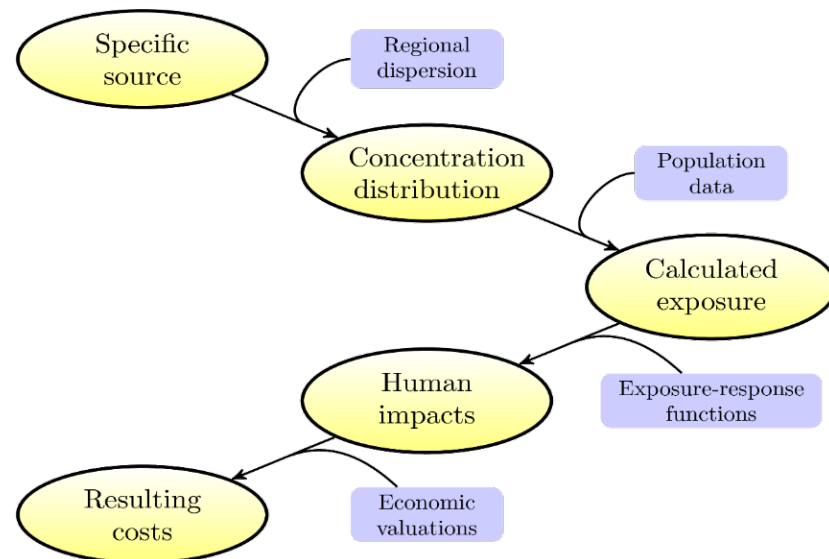
~4600 due to total air pollution.

~1100 due to Danish emissions.

We 'export' air pollution related to about 2000 premature deaths in other countries ....

Costs: ~11 billion Euros per year.

The EVA System – Economic Valuation Of Air Pollution:



Atmos. Chem. Phys., 13, 7747–7764, 2013  
www.atmos-chem-phys.net/13/7747/2013/  
doi:10.5194/acp-13-7747-2013  
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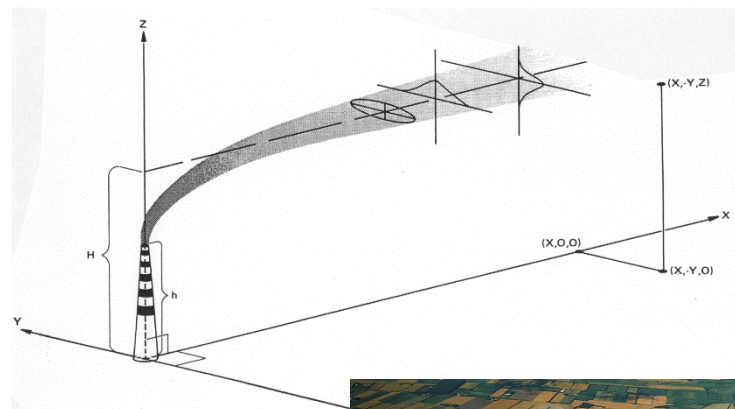


**Assessment of past, present and future health-cost externalities of air pollution in Europe and the contribution from international ship traffic using the EVA model system**

J. Brandt<sup>1</sup>, J. D. Silver<sup>1</sup>, J. H. Christensen<sup>1</sup>, M. S. Andersen<sup>1</sup>, J. H. Bonlokke<sup>2</sup>, T. Sigsgaard<sup>2</sup>, C. Geels<sup>1</sup>, A. Gross<sup>1</sup>, A. B. Hansen<sup>1</sup>, K. M. Hansen<sup>1</sup>, G. B. Hedegaard<sup>1,2</sup>, E. Kaas<sup>1</sup>, and L. M. Frohn<sup>1</sup>

# OML and OML-DEP

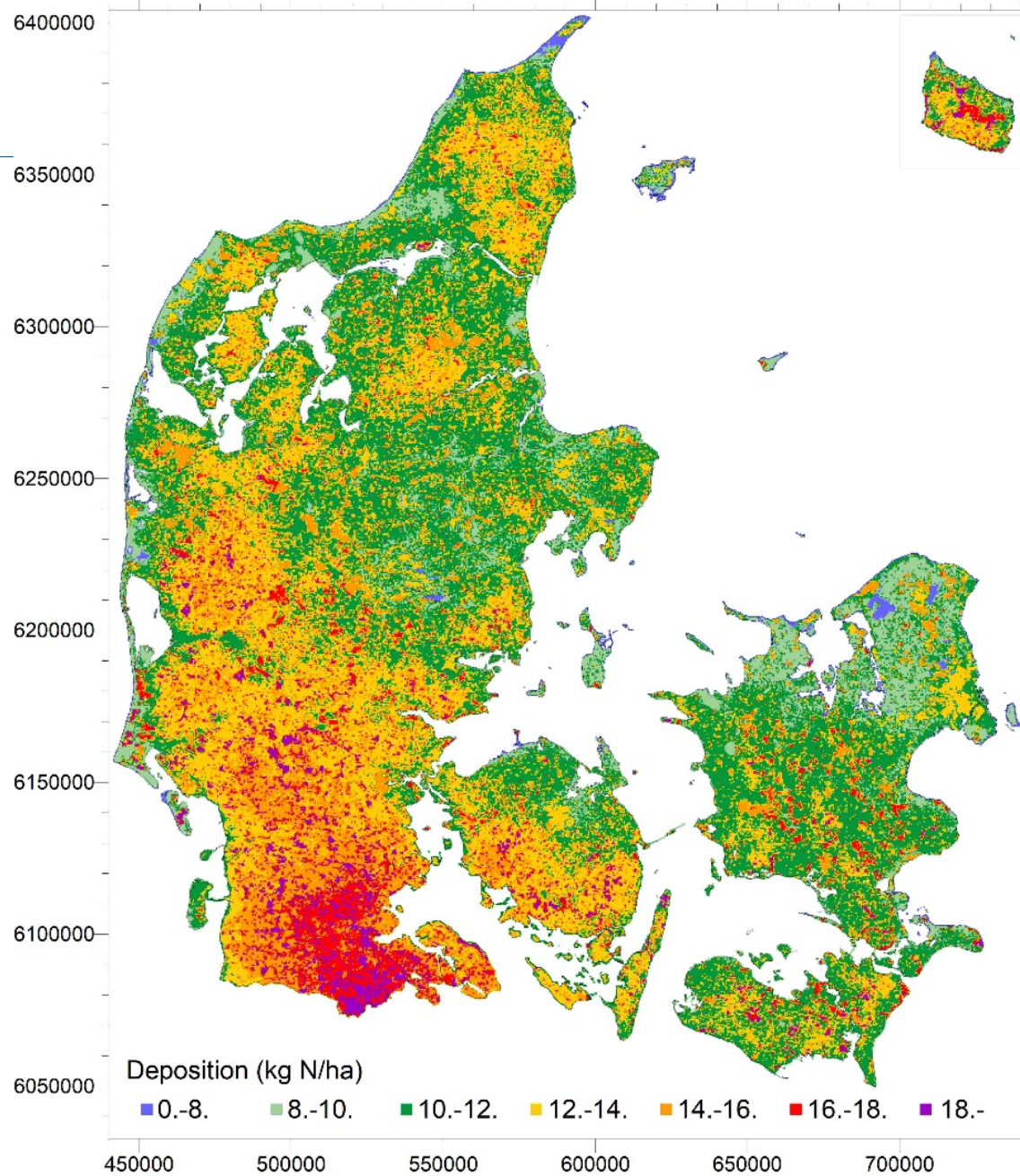
- › The Gaussian plume model **OML-Multi**: standard tool for impact assessments of all **industrial sources** in DK.
- › **OML-DEP**: impact assessments of **agricultural sources**.
- › Dynamic  $\text{NH}_3$  emission model.
- › Incl. dry deposition of ammonia.
- › Setup for specific nature areas with a 16 km x 16 km domain (400x400 m<sup>2</sup> resolution).





# AARHUS DEPARTMENT OF ENVIRONMENTAL SCIENCE

## Total N deposition – e.g. part of our National monitoring





# Challenges

- › Underestimation of PM by DEHM and UBM (ca. 33% when compared to observations).
  - Evaluation of e.g. SOA somewhat limited ....
- › We apply the official EMEP emissions for the reporting + Danish. But we know that TNO REF2 emissions are somewhat better (e.g. in terms of the condensable fraction of residential combustion)....
- › No standard for UFP emissions.
- › ‘Frozen model’ applied for a number of years ...
- › On our wish-list: development of an impact assessment tool for nature (less consolidated).

