

# THE DANISH LAGRANGIAN MODEL (DALM) LOCAL-SCALE LONG-TERM AIR POLLUTION MODELING IN DENMARK

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# Motivation

“Air pollution is now recognized as the single largest environmental threat to human health and well-being” (WHO, 2021)

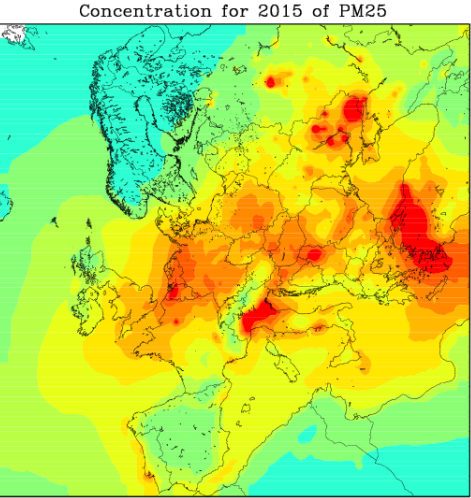
- Yearly worldwide premature deaths: 6.7 million (2019)
- Yearly Danish premature deaths: 4 600 (2019)
- **Epidemiological studies** → **health impact assessments**
- From **extreme air pollution events** to **multidecadal exposure studies**



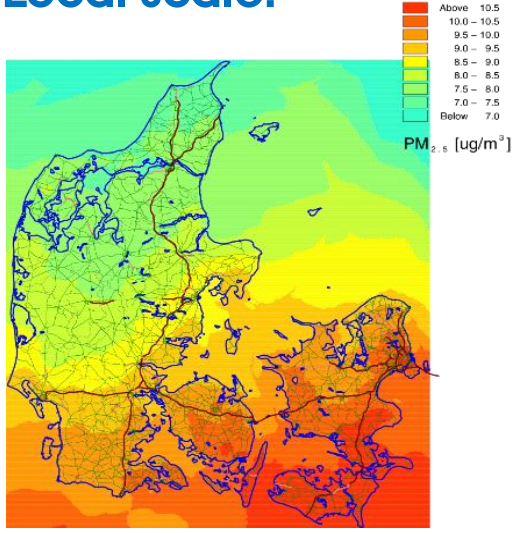
Sources: Brandt et al., 2013; Ellermann et al., 2021; Hertel et al., 2013; WHO, 2021

# Aarhus University - Model Framework

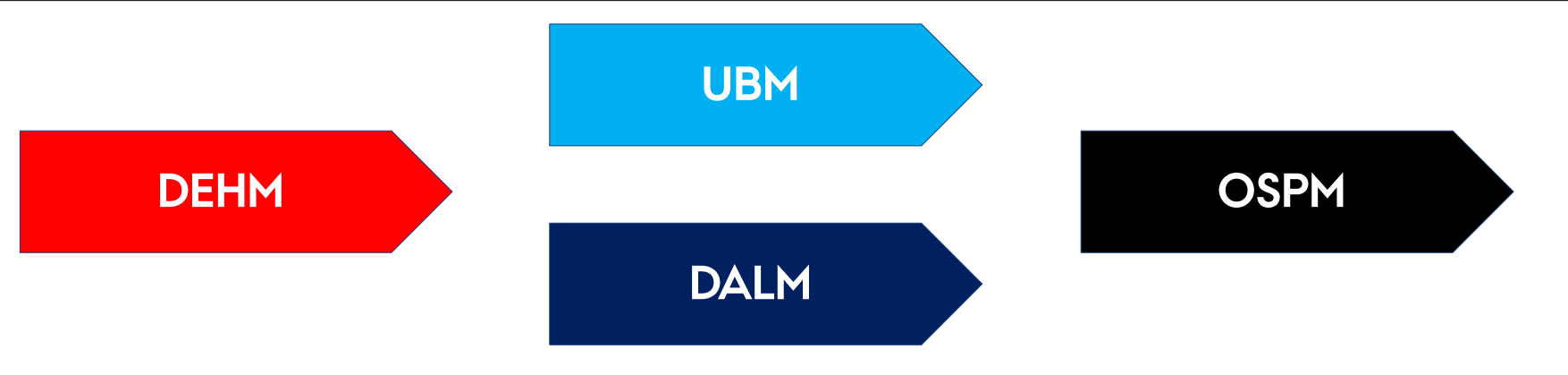
## Regional scale:



## Local scale:



## Street scale:



- Human and nature exposure
- Health effects
- Socio-economic costs

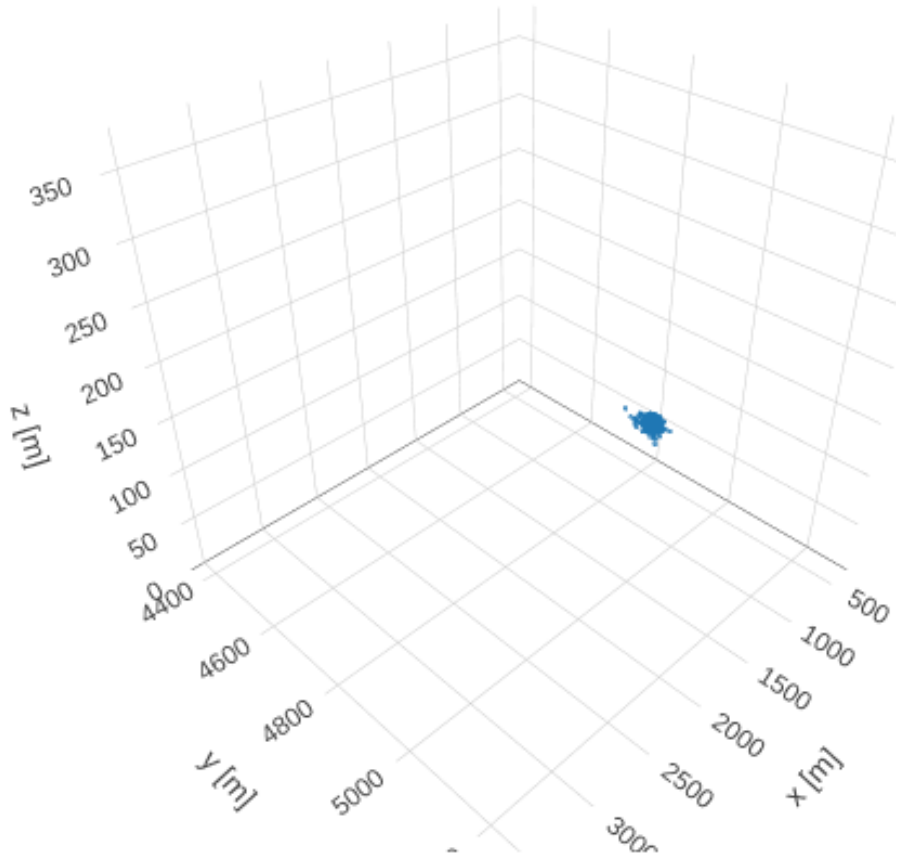
Sources: Brandt et al., 2001; Christensen 1997; Ketzel et al., 2012

# Main Scientific Question

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By applying comprehensive methodologies related to physics and numerical methods, is it possible to **develop a new local-scale Lagrangian air pollution model for Denmark, the DANish Lagrangian Model (DALM)**, that is able to compute sufficiently accurate air pollution concentrations for use in **long-term exposure assessments**?

# DALM – Overview

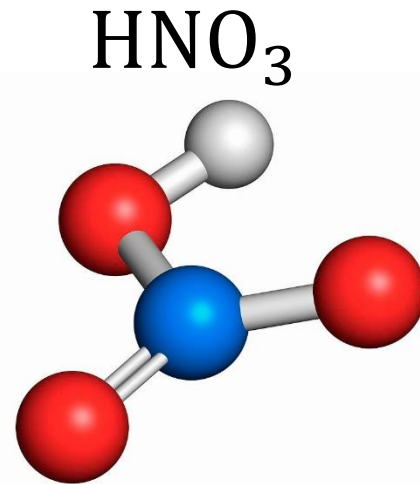
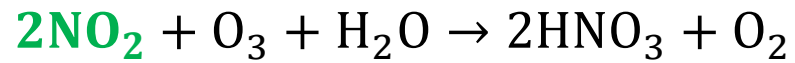


- **Boundary conditions: DEHM**
- **Meteorology: WRF**
- **Emissions: SPREAD (DK), STEAM (shipping), and EMEP (non-DK) – time variation profiles**
- **3D advection** and **dispersion**
- **Adaptive time steps** and **concentration kernels**
- Linear  $\text{NO}_2$  and  **$\text{NO-NO}_2\text{-O}_3$  photochemistry**
- **Land use classes** and roughness
- **Dry deposition**
- **Long-term local-scale** simulations of Denmark with **DALM** are computationally very affordable!

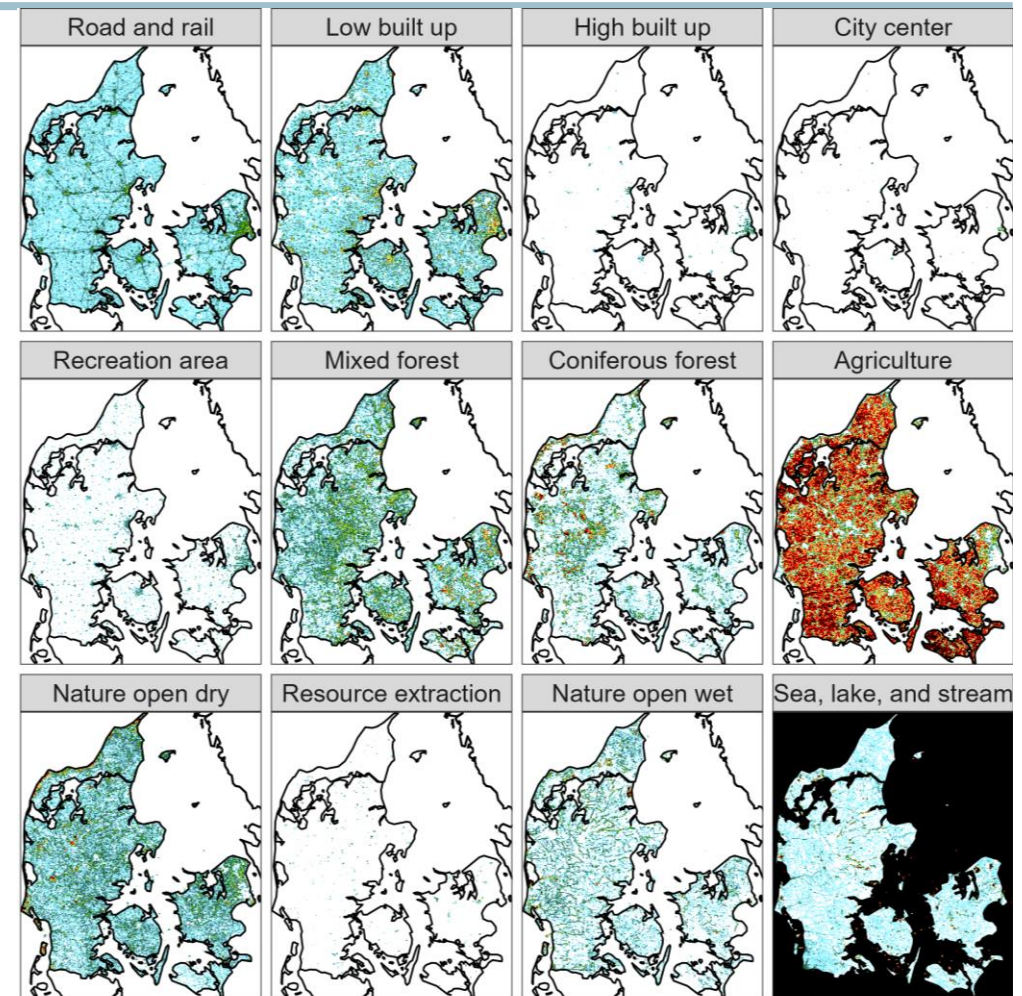
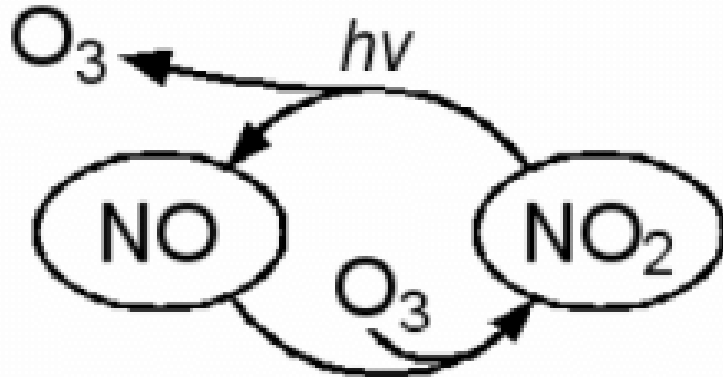
Source: Andersen et al., 2024



# Chemistry and Dry Deposition



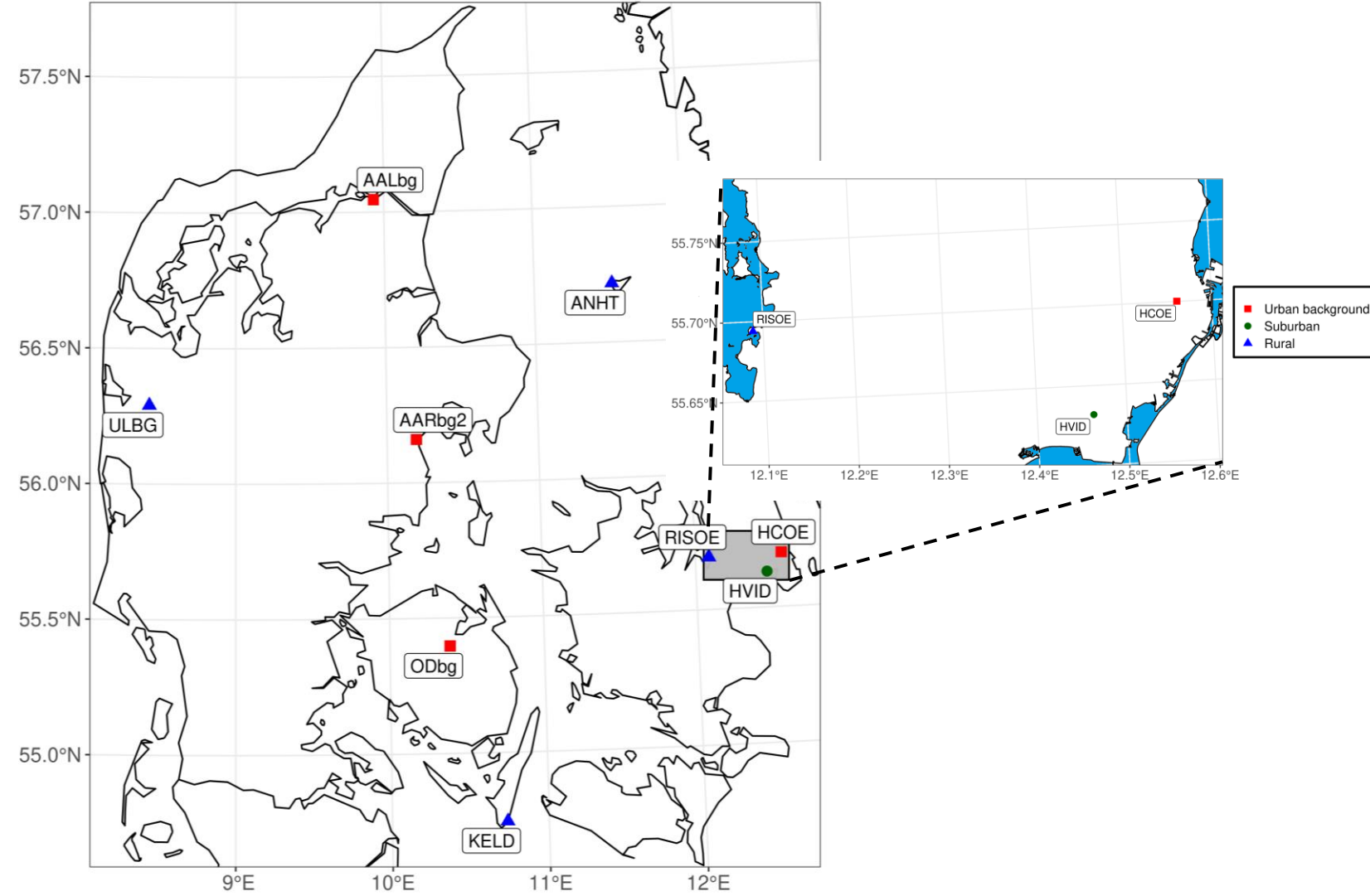
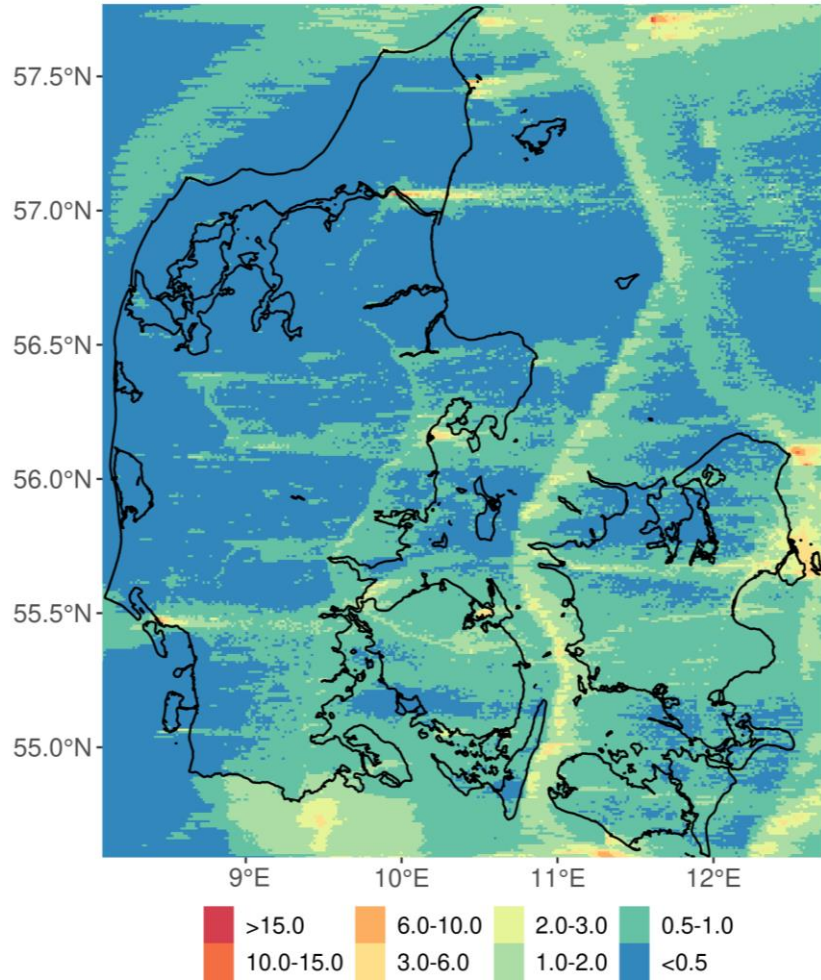
Photochemical scheme NO-NO<sub>2</sub>-O<sub>3</sub>:



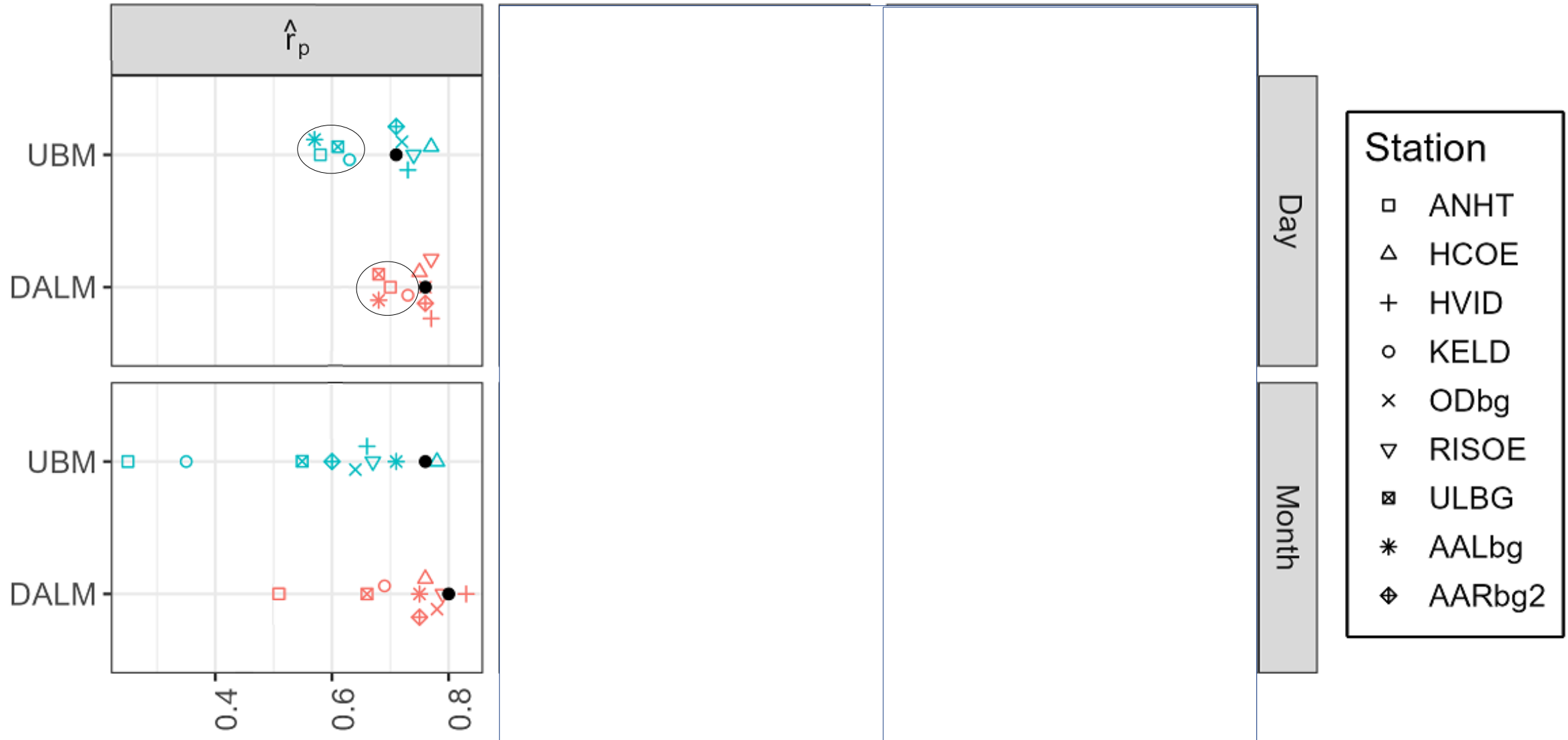
Sources: Seinfeld and Pandis, 2016; Berkowicz, 2000; Brandt et al., 2001; Ketzel et al., 2012; Levin et al., 2017

# Model Evaluation

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# Model Evaluation, 2016 – 2022: NO<sub>2</sub>

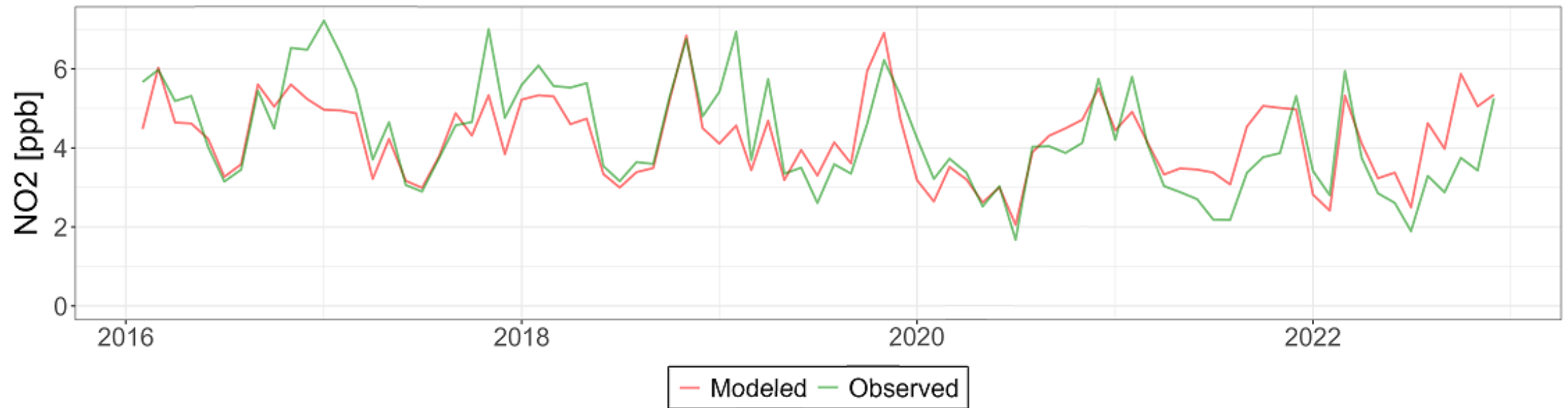




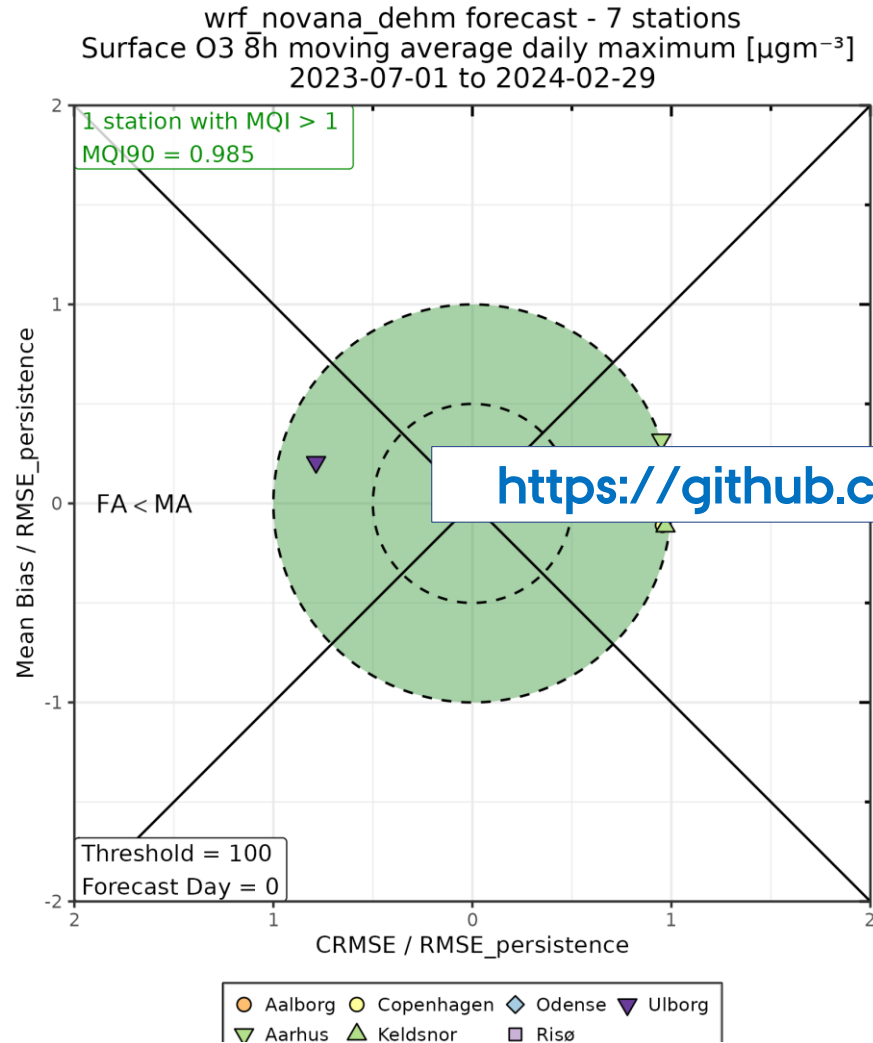
# Model Evaluation, 2016 – 2022: O<sub>3</sub>



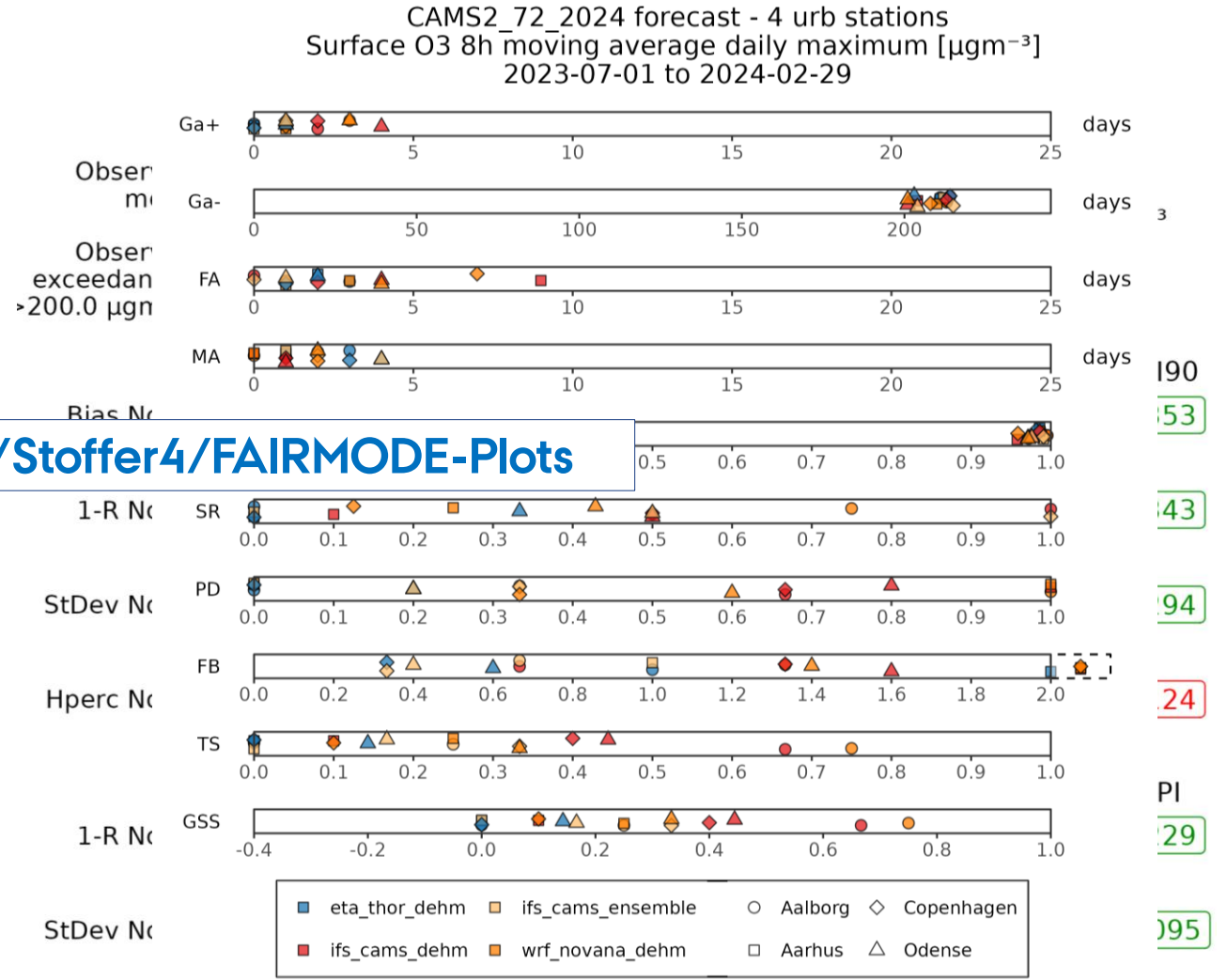
# Multiyear Averaged Time Series - DALM



# FAIRMODE Model Benchmarking - DALM



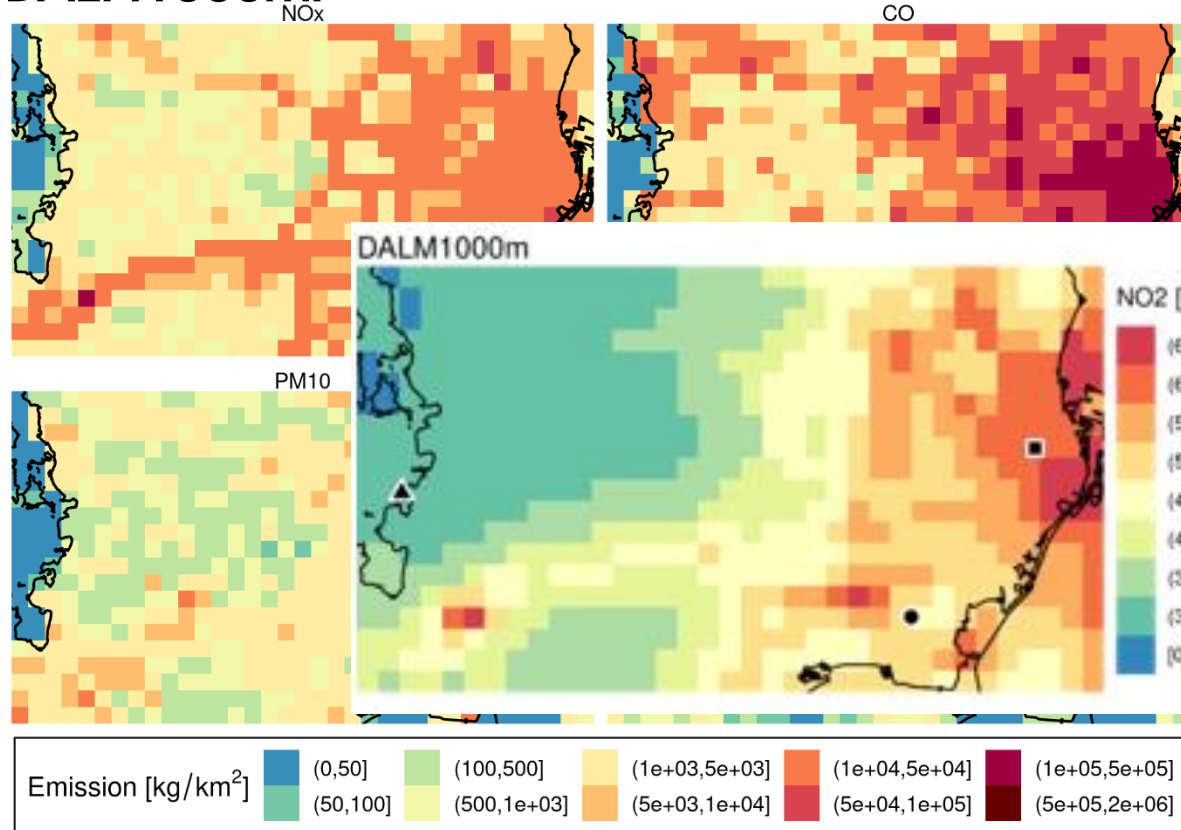
<https://github.com/Stoffer4/FAIRMODE-Plots>



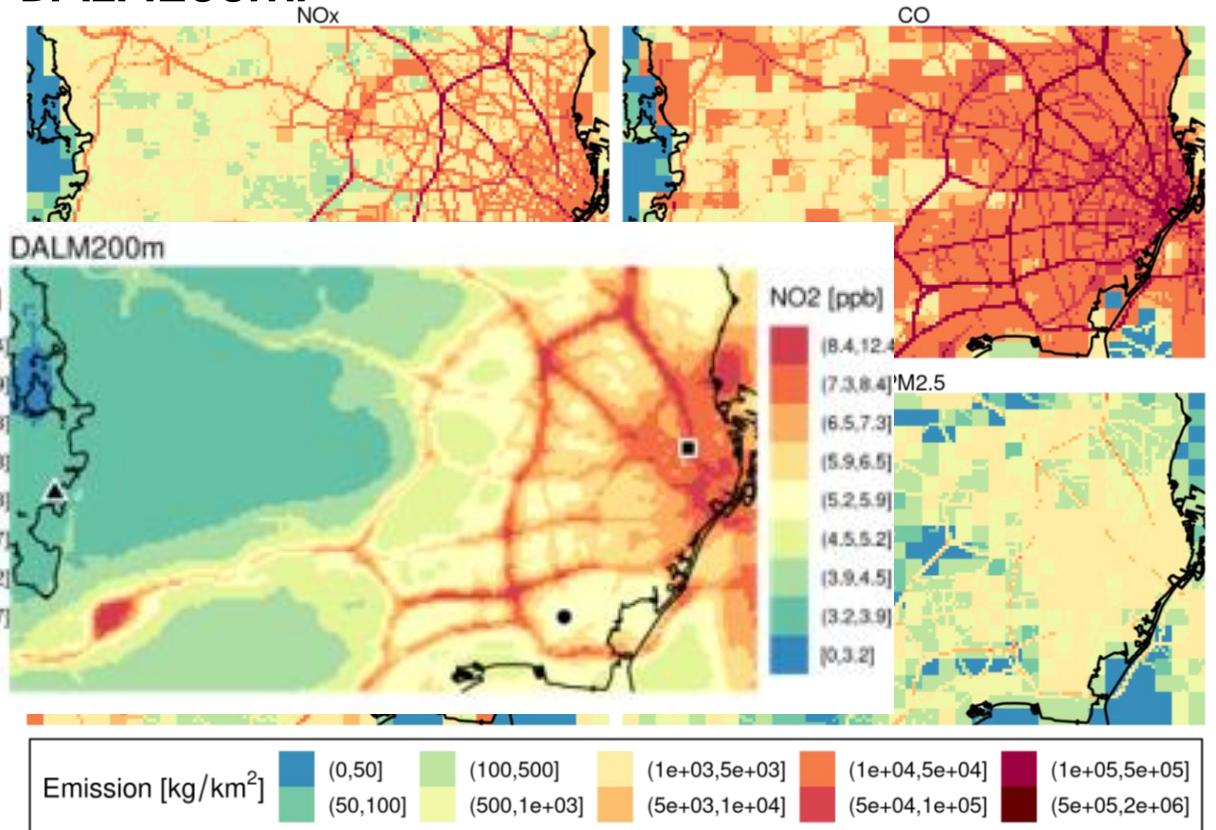
Source: Janssen and Thunis, 2022

# High-Resolution Traffic Emissions - DALM

DALM1000m:



DALM200m:



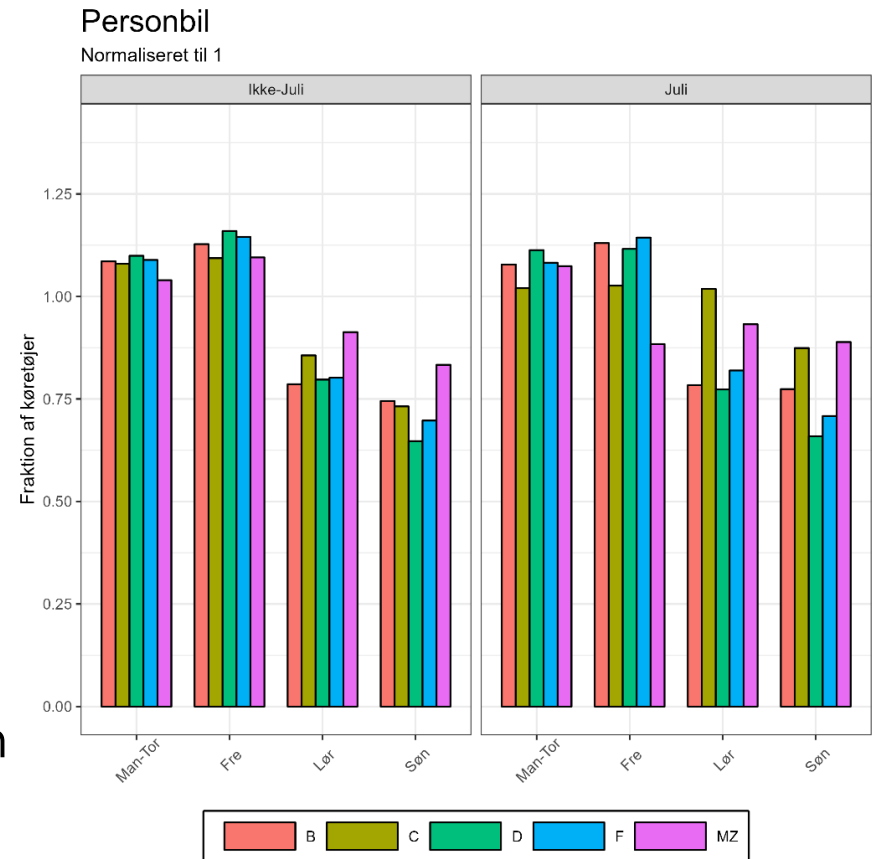
Sources: Jensen et al., 2019; Johansson et al., 2017; Mareckova et al., 2008; Olesen et al., 2015

# Conclusion / Future Work

- Local-scale **LPDM** with **DALM** is useful and applicable for **multiyear/decade-long** simulations
  - Useful as **proxy** for **lifetime exposure** to ambient air pollution (future studies)
- Alternative to **UBM** for some applications – **computationally** more expensive

## Outlook:

- New **time variation profiles** – road traffic and wood stoves
- Better representation of **boundary conditions**
- **Wet deposition** scheme
- **Higher spatial resolution** emission sources
- Couple to **Economic Valuation of Air Pollution (EVA)** system







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<https://github.com/Stoffer4/FAIRMODE-Plots>

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# Extra Slides

# FAIRMODE Model Benchmarking - 1 Year

