EVALUATION OF THE OPEN ROAD SOURCE MODEL OML-HIGHWAY FOR SEVERAL FIELD DATASETS

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Outline

- **Background / Motivation**
- **OML-Highway – model description**
- **Evaluation of the OML-Highway**
- **Example of application in Denmark**
- **Conclusion**

Background / Motivation

- **Assessment of air pollution is a requirement in environmental impact assessments (EIA) of new major roads**
  - **Protection of human heath (Limit values)**
  - **Protection of sensitive nature areas**
- **OML-Highway model was developed (2006-2009) to enhance information about air pollution in EIAs of major road projects**
- **OML-Highway model applied in EIAs of motorways and other main roads in Denmark since 2010**

OML-Highway Model

- **Based on OML -Multi**
  - a local-scale Gaussian air pollution model (since 198x)
  - Using Monin-Obukhov boundary layer scaling (MOST)
  - Area and point sources

- **Traffic produced turbulence (TPT) is added:**
  - traffic intensity, type of vehicles and speed (as in OSPM model)

$$\sigma_{y,z}^2 = \sigma_{y_a,z_a}^2 + \sigma_{y_0,z_0}^2$$

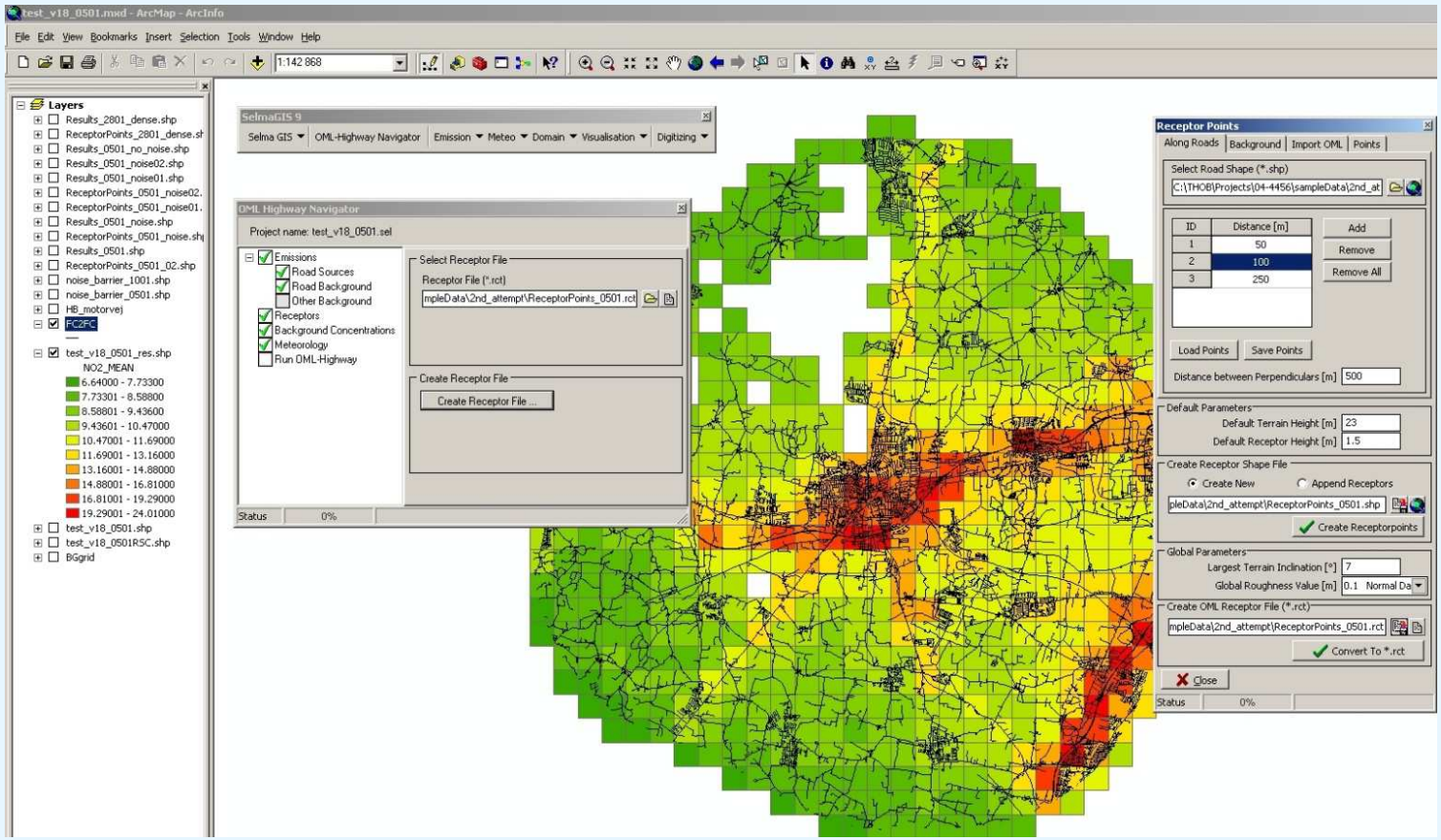
  - but decays in an exponential manner with transport time

$$\sigma_0(t) = \sigma_{\text{initial}} + u_{\text{TPT}}\tau\left[1 - \exp\left(-\frac{t}{\tau}\right)\right],$$

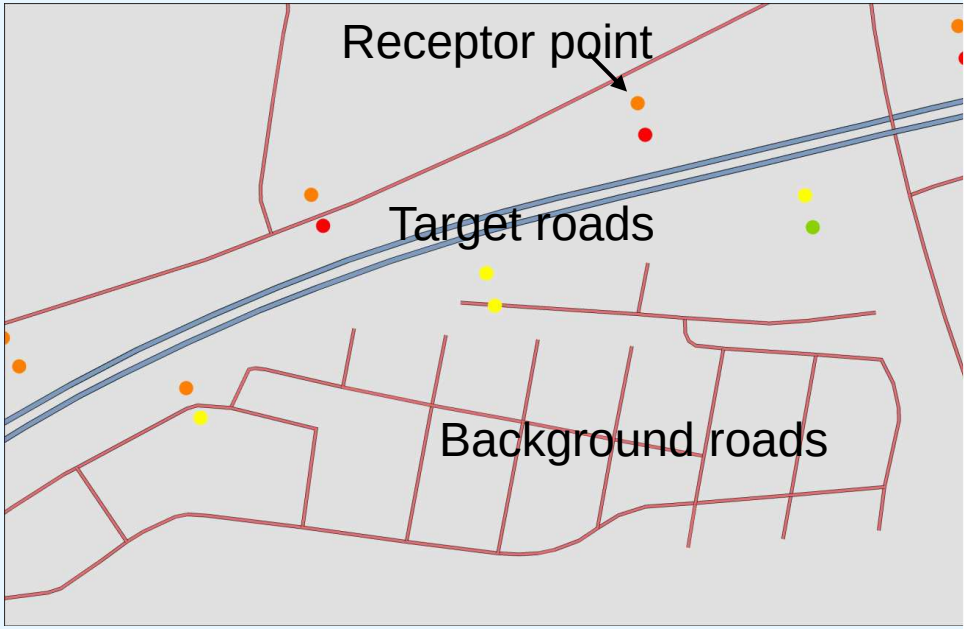
where t is the transport time (s), τ is the time scale for the decay of TPT (s) and $\sigma_{\text{initial}} = 3.2$ m

User interface based on SELMA^{GIS}

- **SELMAGIS – a tool for modelling and visualisation of air quality data based on ArcGIS™**
- **OML-Highway is implemented as an extension in ArcGIS™**



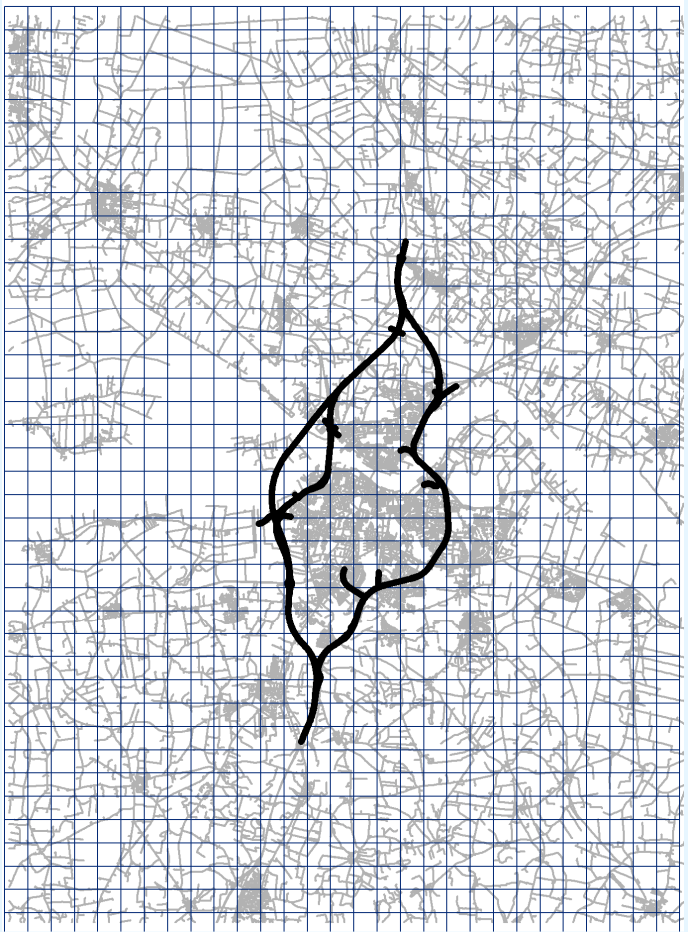
Input and output

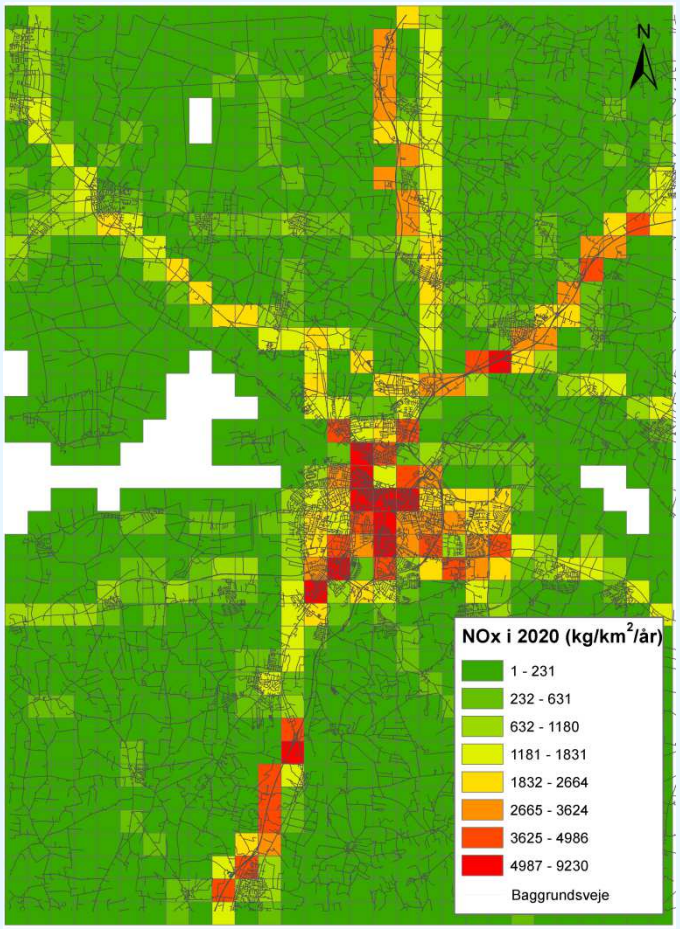


- **Input**
  - traffic data on a GIS map
  - receptor points
  - meteorological data
  - regional background concentration data
  - emission data from other sources (optional)
- **Output**
  - hourly concentrations for receptor points
  - concentration data: statistical and time-serie data
  - NO_x, NO_2, O_3, $PM_{2.5}$ og PM_{10}, particle numbers, CO, and benzene
  - CO_2 emissions (based on fuel consumption)

Target versus background roads

› **Smaller / more distant roads summarized as area sources**





Validation of OML-HW

› Berger et al. 2010, 3 data set, 4 modells

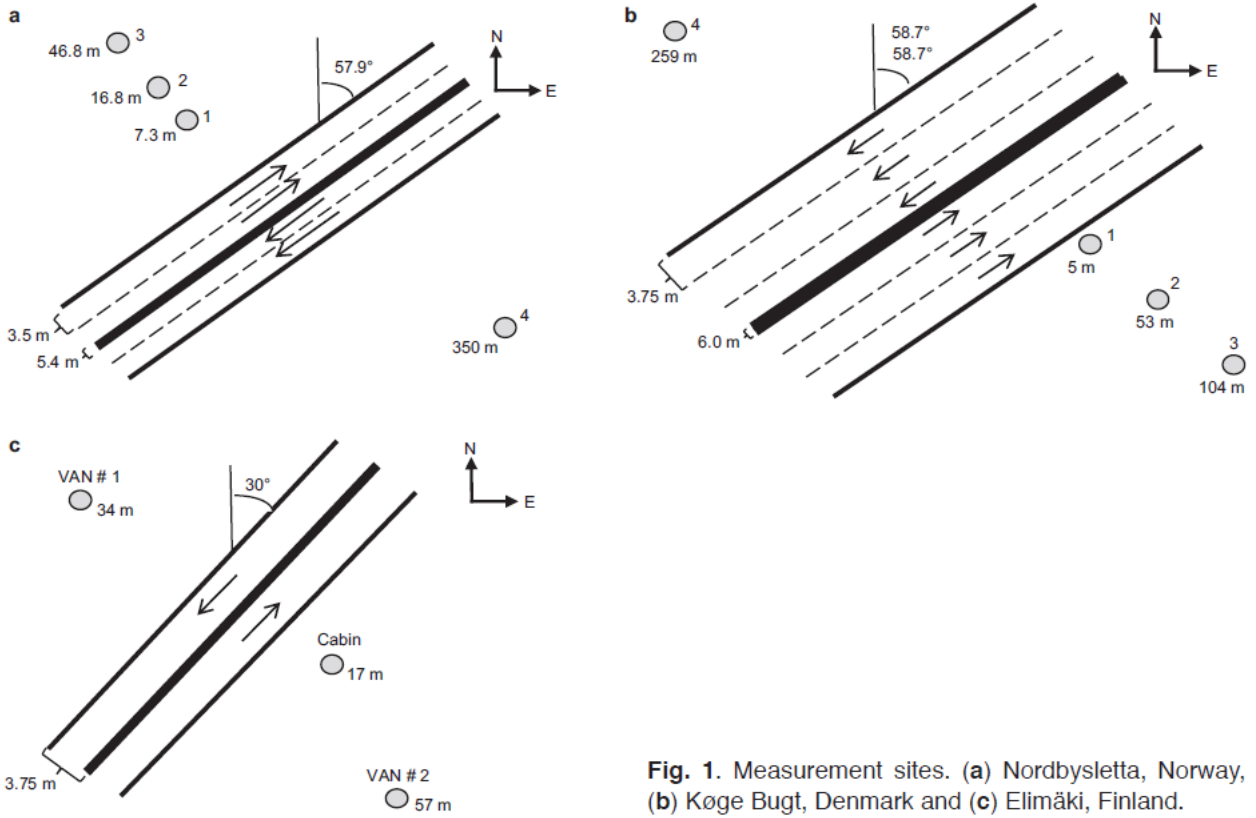


Fig. 1. Measurement sites. (**a**) Nordbysletta, Norway, (**b**) Køge Bugt, Denmark and (**c**) Elimäki, Finland.

Validation of OML-HW

› **HIWAY2-AQ OML-Highway CAR-FMI WORM**

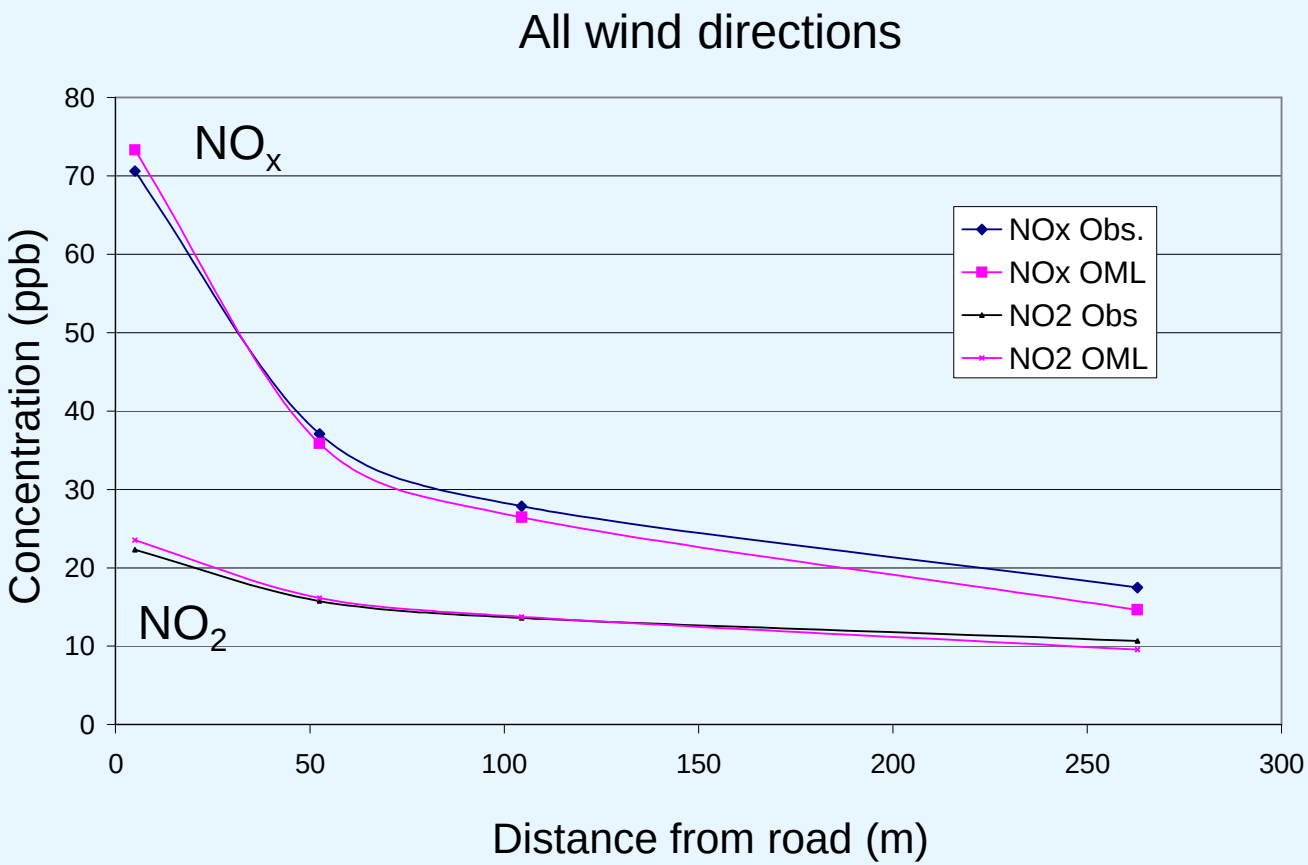
Table 3. Coefficient of determination, R^2, for all models applied to all data, for both non-normalised and *Q*-normalised results.

	HIWAY2-AQ Non-norm.	HIWAY2-AQ *Q*-norm.	OML-Highway Non-norm.	OML-Highway *Q*-norm.	CAR-FMI Non-norm.	CAR-FMI *Q*-norm.	WORM Non-norm.	WORM *Q*-norm.
Norwegian data								
St. 1	0.50	0.18	0.72	0.69	0.50	0.23	0.72	0.42
St. 2	0.52	0.21	0.68	0.60	0.46	0.28	0.68	0.47
St. 3	0.48	0.20	0.62	0.53	0.46	0.37	0.64	0.49
Danish data								
St. 1	0.38	0.18	0.75	0.65	0.49	0.25	0.65	0.28
St. 2	0.34	0.24	0.74	0.61	0.41	0.36	0.70	0.36
St. 3	0.31	0.27	0.71	0.56	0.43	0.50	0.71	0.43
Finnish data								
VAN#1	0.51	0.49	–	–	0.47	0.44	0.51	0.51

Table 4. Relative bias, RB, for all models applied to all data, for both non-normalised and *Q*-normalised results.

	HIWAY2-AQ Non-norm.	HIWAY2-AQ *Q*-norm.	OML-Highway Non-norm.	OML-Highway *Q*-norm.	CAR-FMI Non-norm.	CAR-FMI *Q*-norm.	WORM Non-norm.	WORM *Q*-norm.
Norwegian data								
St. 1	0.02	–0.16	–0.21	–0.22	–0.11	–0.16	–0.31	–0.34
St. 2	0.13	–0.07	–0.19	–0.19	0.03	–0.02	–0.26	–0.29
St. 3	0.12	–0.10	–0.20	–0.22	0.18	0.12	–0.24	–0.28
Danish data								
St. 1	0.16	–0.27	0.04	–0.18	0.42	0.08	0.11	–0.22
St. 2	0.15	–0.35	0.00	–0.30	0.67	0.24	0.13	–0.26
St. 3	0.06	–0.42	0.01	–0.31	0.74	0.29	0.10	–0.28
Finnish data								
VAN#1	–0.13	–0.14	–	–	0.09	0.09	–0.48	–0.49

Validation for NO_x and NO_2 in 2003

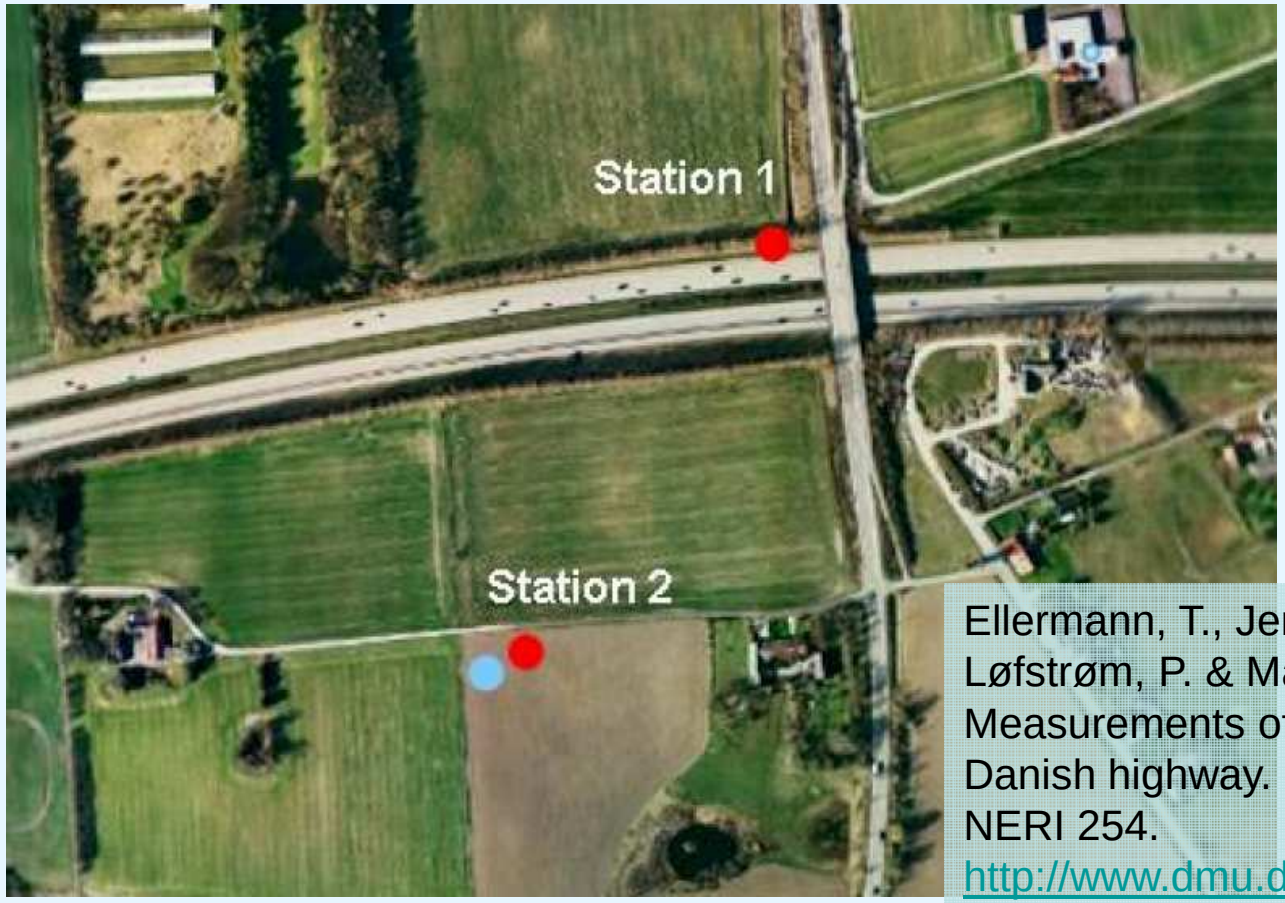


Køge Bugt Motorway

(Jensen et al. 2004a,b)

Newer Danish data set (Highway 21)

- **Only two stations + met. mast, two month of data**

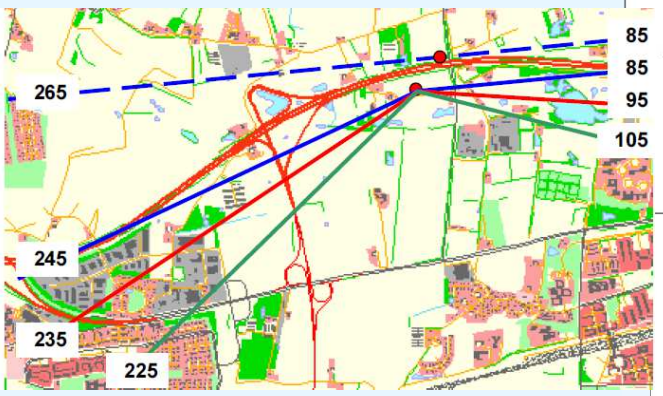


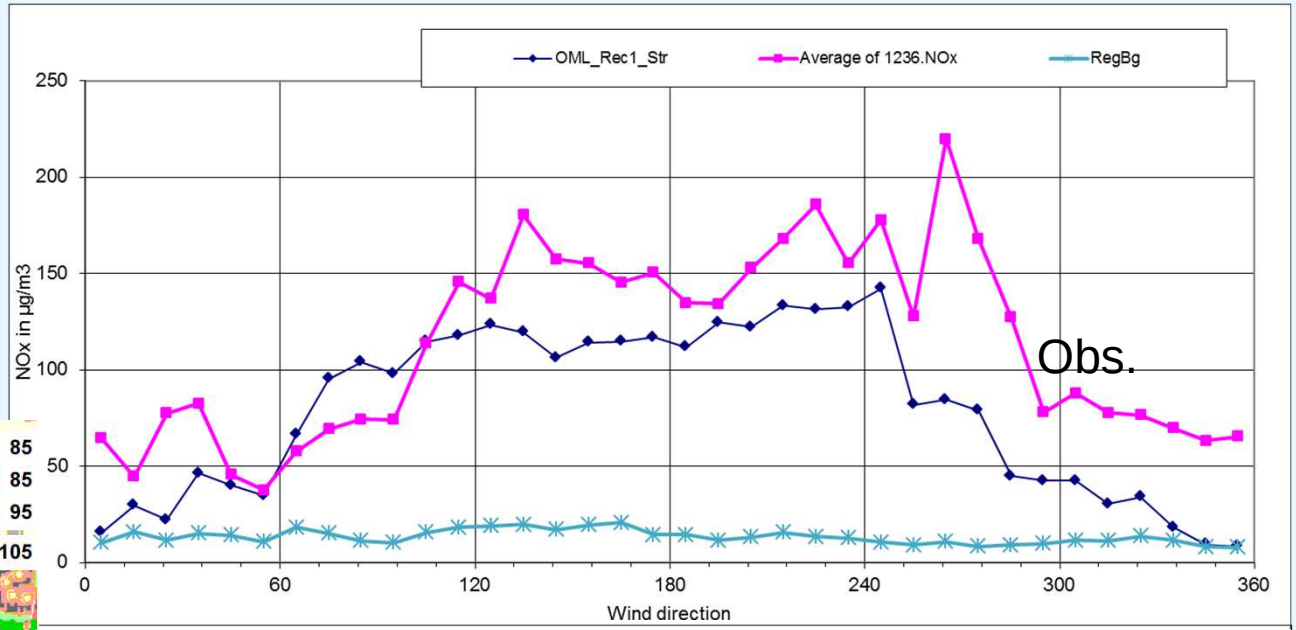
Ellermann, T., Jensen, S.S., Ketzel, M., Løfstrøm, P. & Massling, A. 2009: Measurements of air pollution from a Danish highway. Research Note from NERI 254.
http://www.dmu.dk/Pub/AR254.pdf

Newer Danish data set (Highway 21)

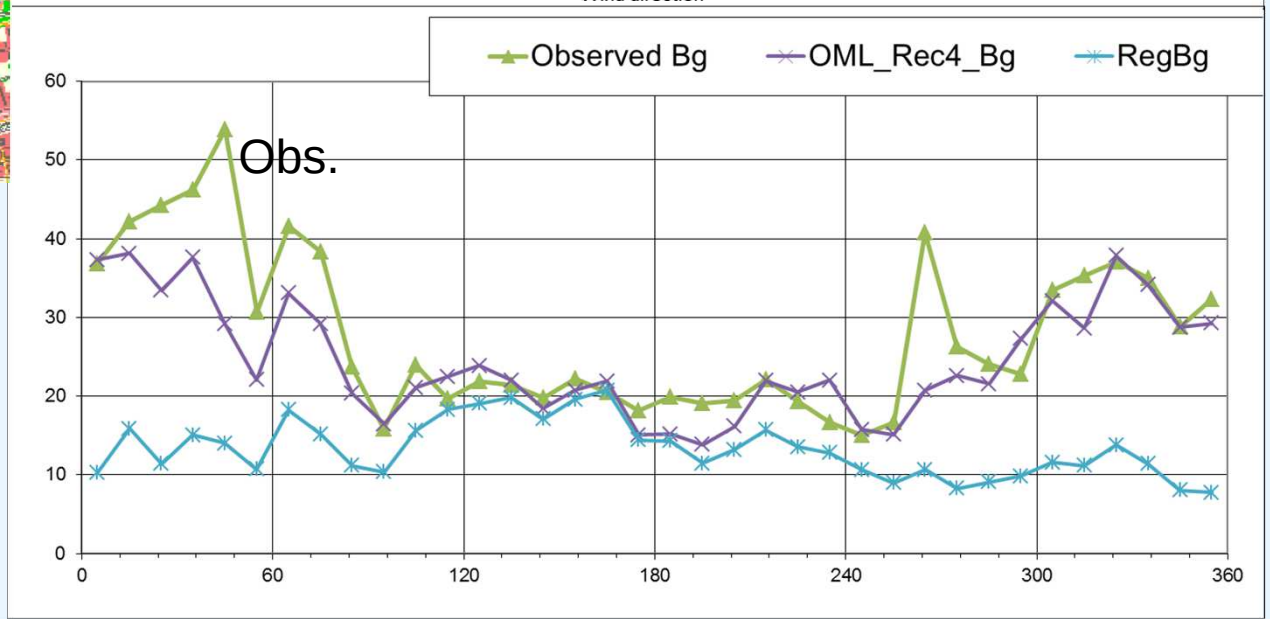
Wind dir.

› **Kerbside →**





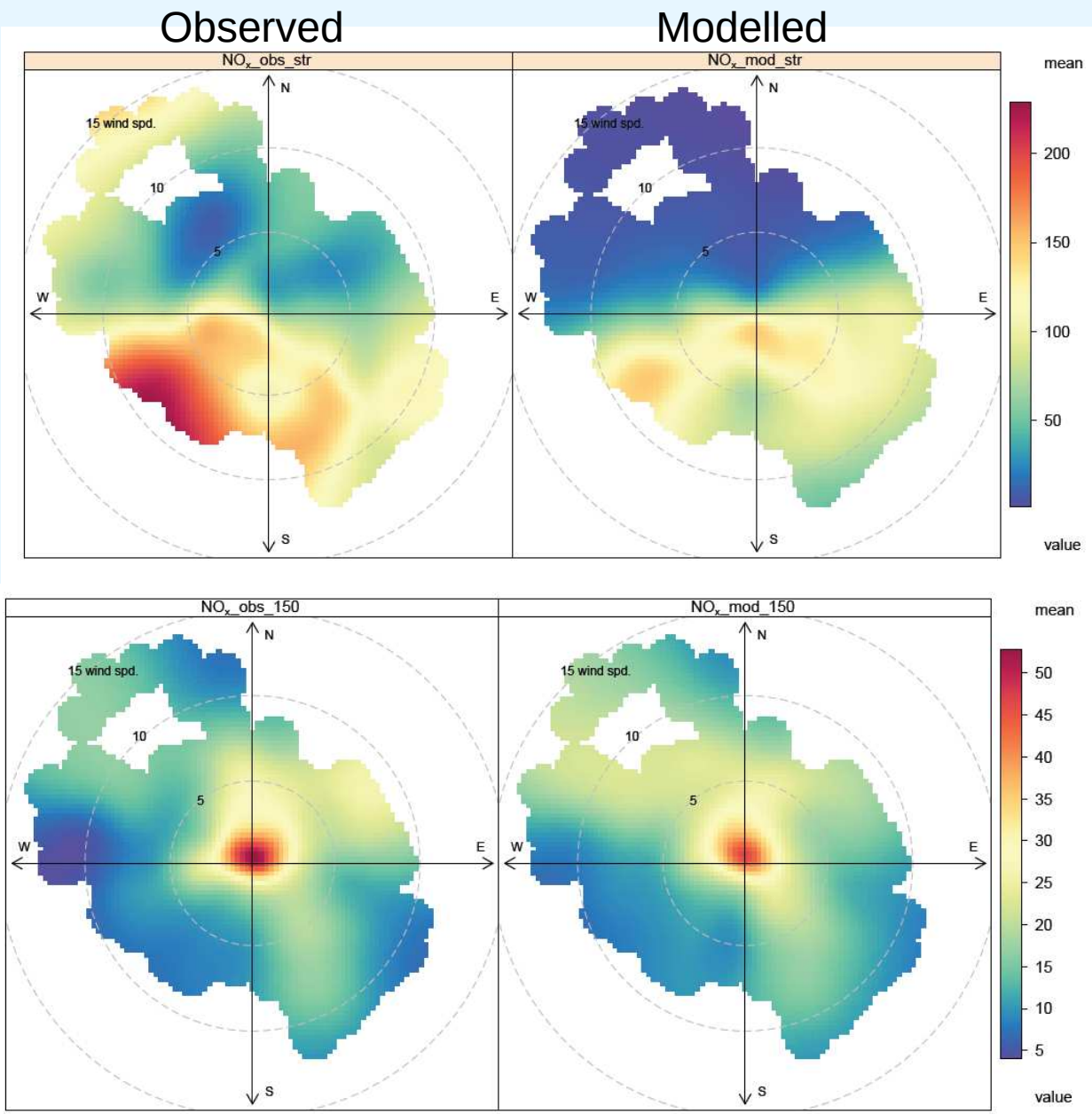
› **150m →**



Wind dir.+WS

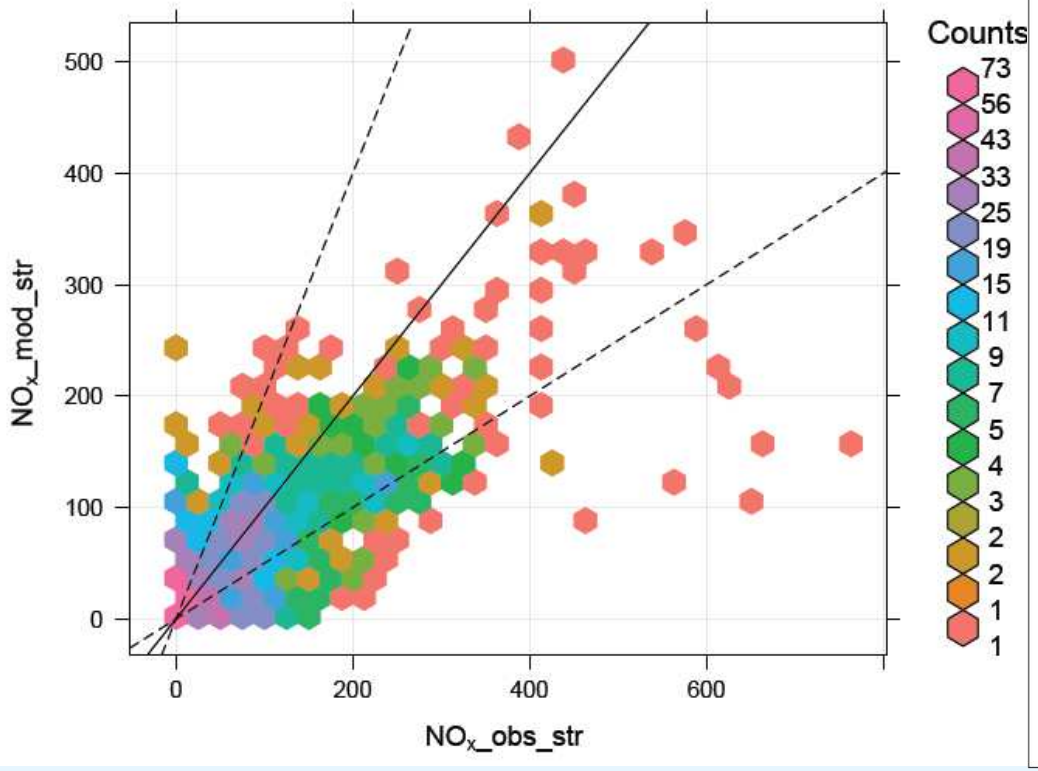
- **Polar plots using 'openair'**
- **Kerbside →**
- **monitor@150m →**

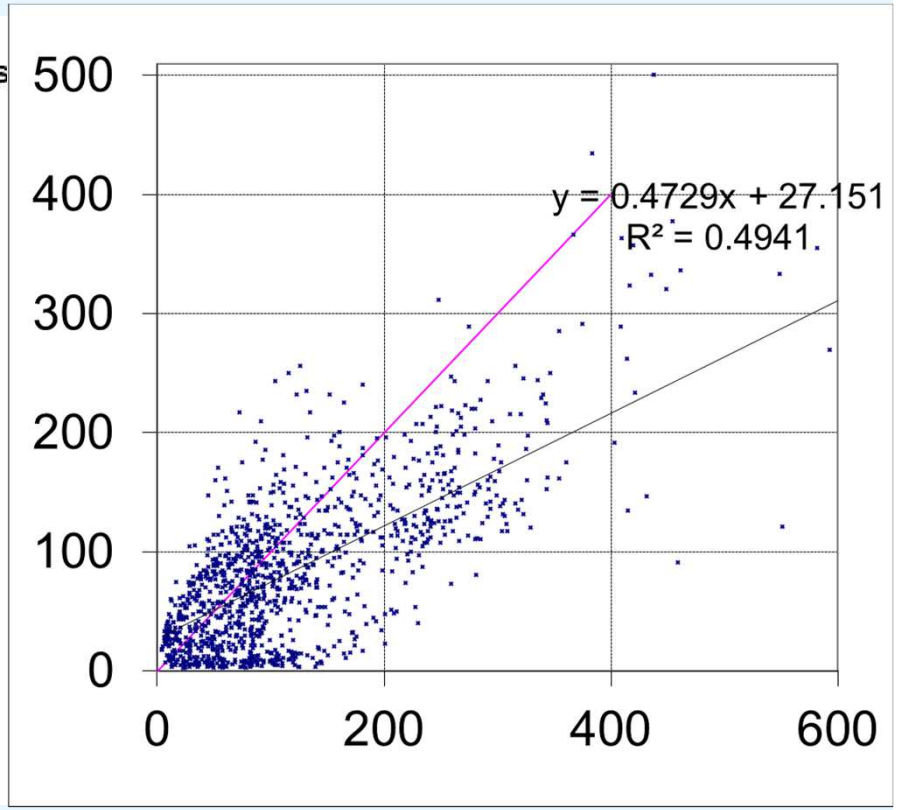
Ref.: David Carslaw and Karl Ropkins (2013). openair: Open-source tools for the analysis of air pollution data. R package version 0.8-5



More validation plots in 'openair'

› ('Hexbin') Frequency-scatterplots





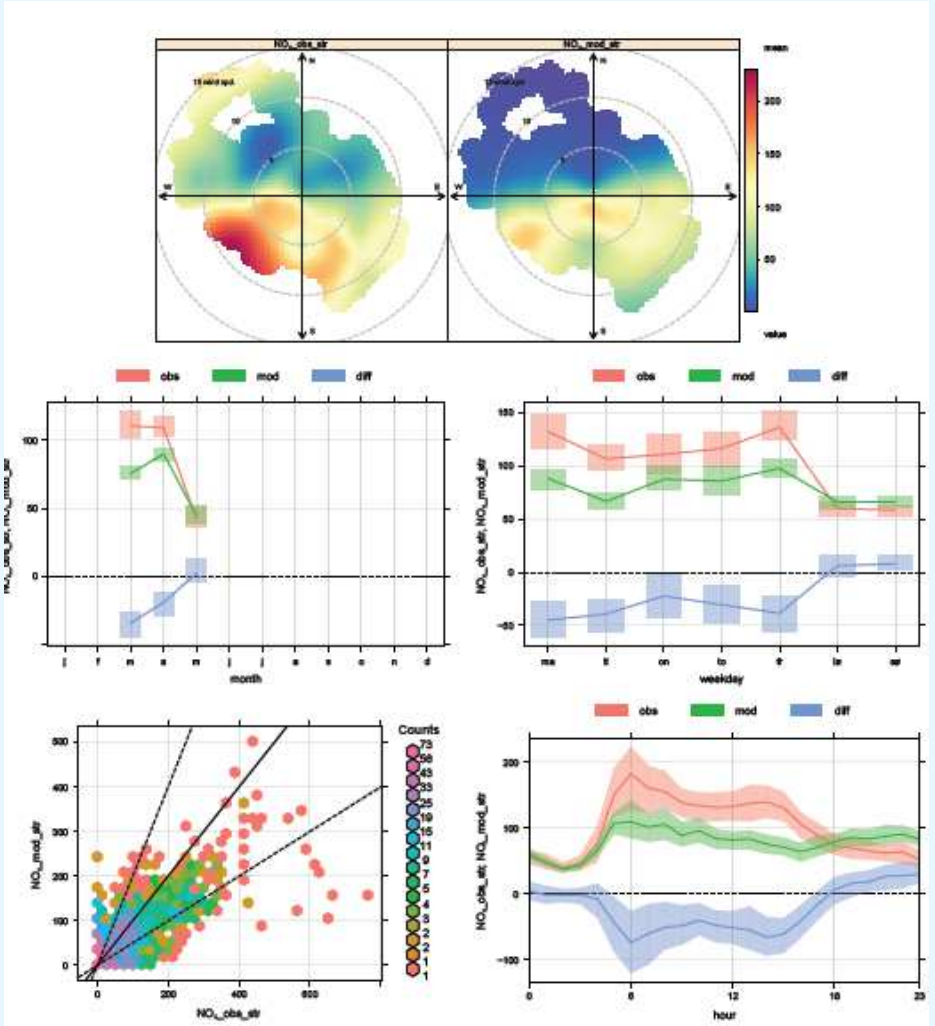
'openair' project

More validation plots in 'openair'

› **Combine statistics and plots as model performance indicators**

weekday	n	FAC2	MB	MGE	NMB	NMGE	RMSE	r	COE
mandag	208	0.52	−44.9	70	−0.34	0.53	94	0.72	0.244
tirsdag	211	0.45	−39.1	62	−0.37	0.59	89	0.61	0.152
onsdag	216	0.43	−22.2	62	−0.20	0.56	90	0.75	0.396
torsdag	180	0.47	−30.5	65	−0.26	0.56	86	0.66	0.205
fredag	167	0.57	−38.4	61	−0.28	0.44	78	0.75	0.323
lørdag	203	0.57	6.2	36	0.10	0.59	47	0.50	0.067
søndag	216	0.58	8.0	35	0.14	0.60	47	0.40	0.083

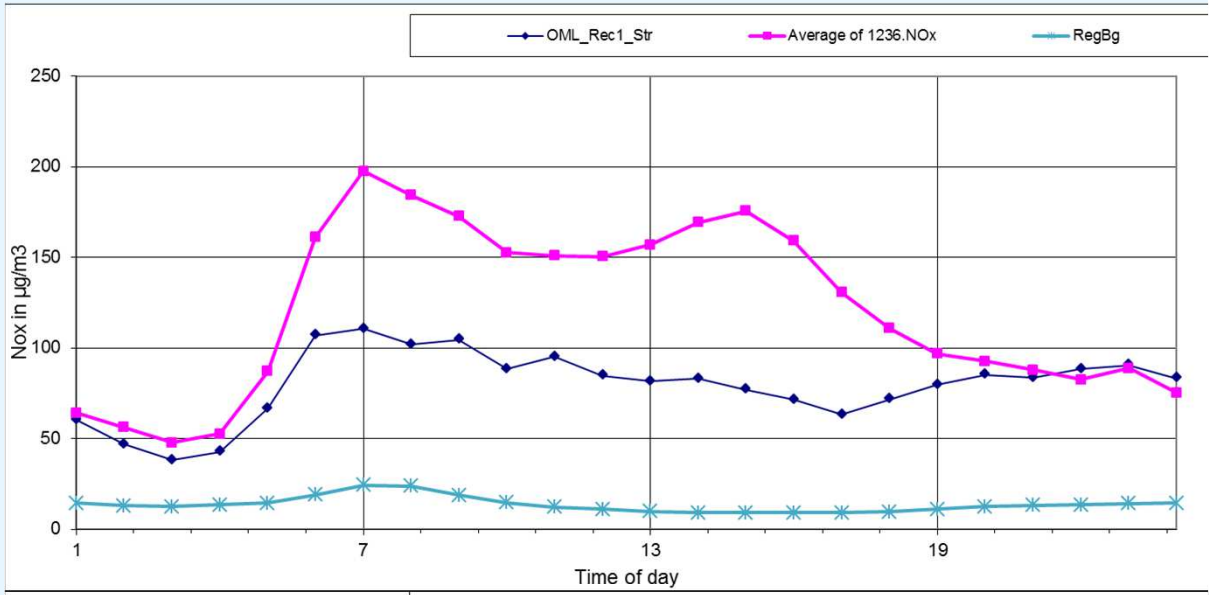
season	n	FAC2	MB	MGE	NMB	NMGE	RMSE	r	COE
spring (MAM)	1401	0.51	−22	55	−0.22	0.55	78	0.67	0.26

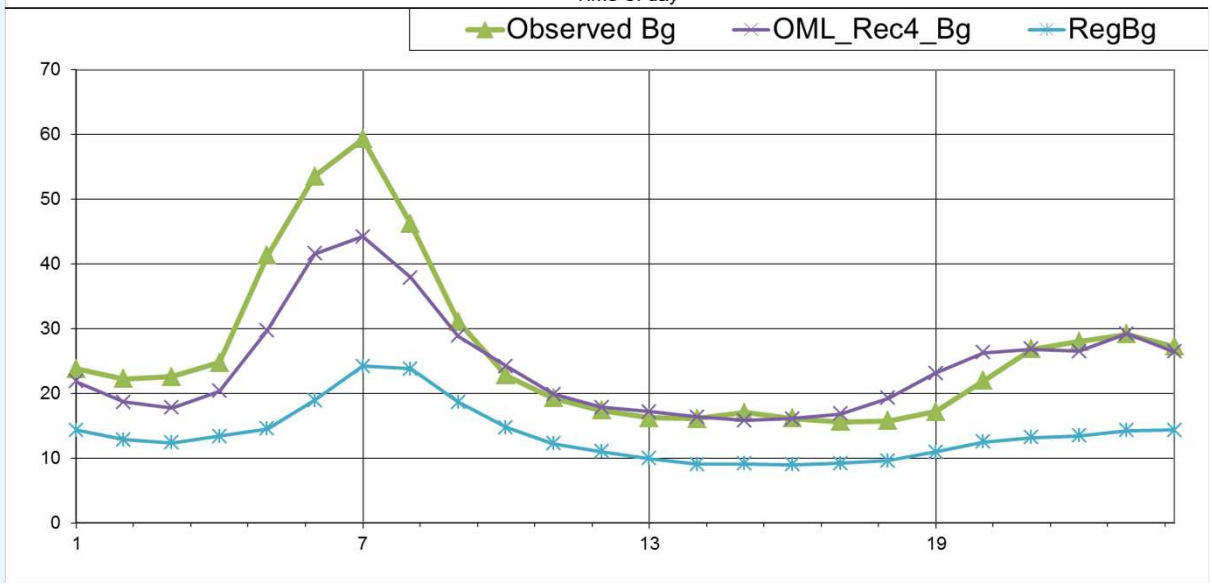


Time of day

- **Kerbside**

- **150m**



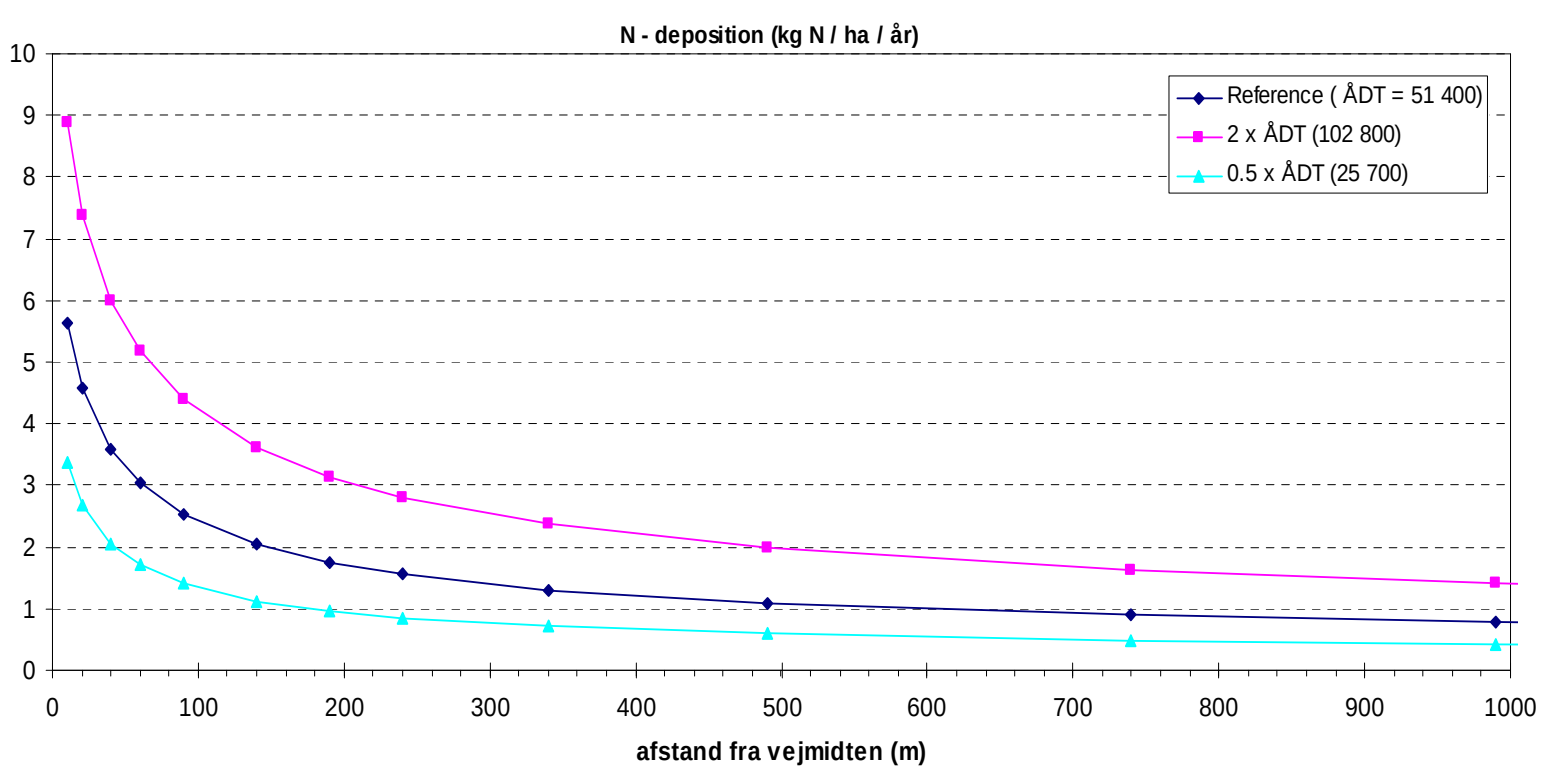


Application of OML-Highway

- **N-Deposition**
- **Impact of noise barriers**
- **Impact of tunnels on adjacent AQ**
- **Systematic mapping of AQ and population exposure along motorway network (present / future scenarios)**

N-deposition in sensitive nature areas

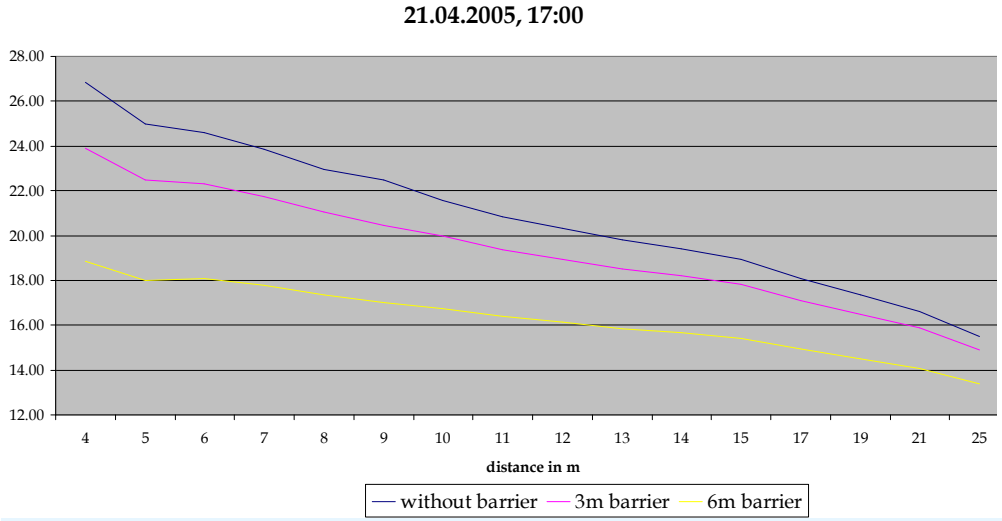
- **Limit of 5…25 kg N / (ha a) dependent on nature type**



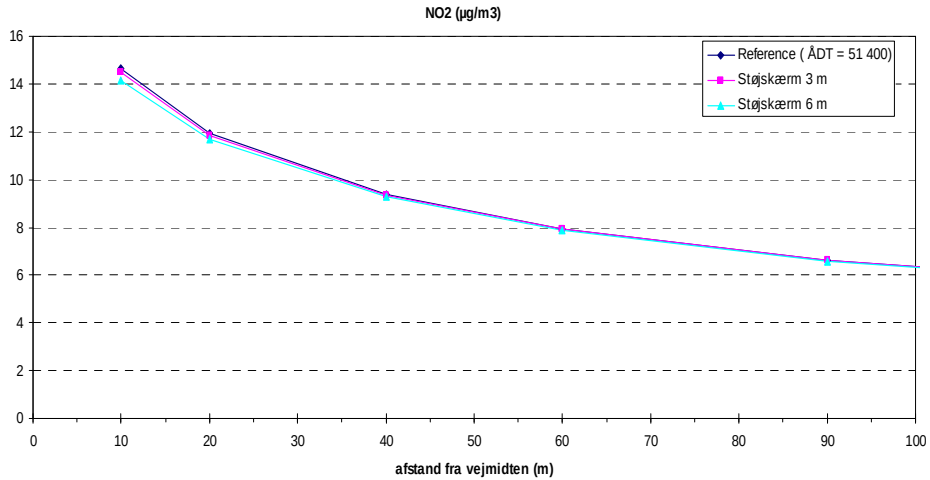
Impacts of noise walls on AQ

- **Reduction larger for 6 m high noise barrier than 3 m high noise barrier**
- **Reduction largest close to noise barrier and reduction diminishes quickly with distance**
- **Effect is due to larger initial dispersion height of plume due to barrier**
- **Less reduction for annual levels due to impacts for all wind directions**

Single cross wind situation

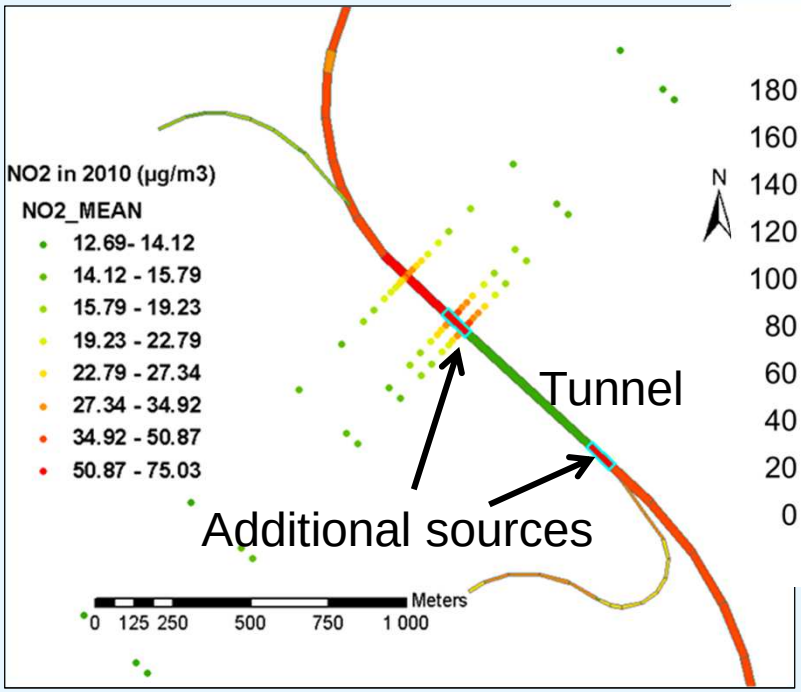


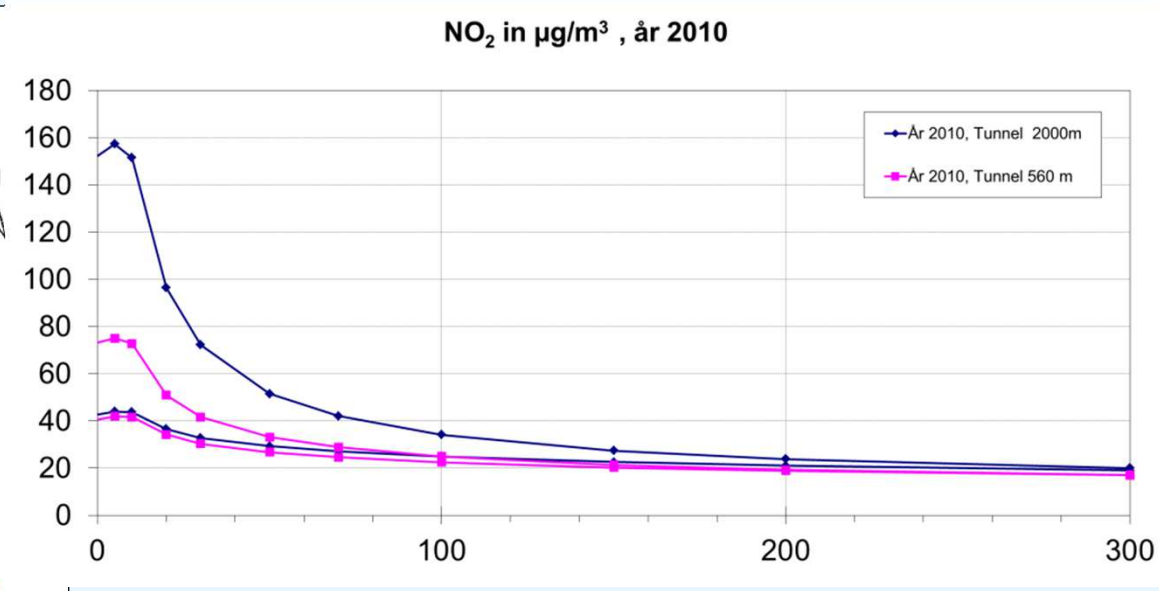
Annual averages



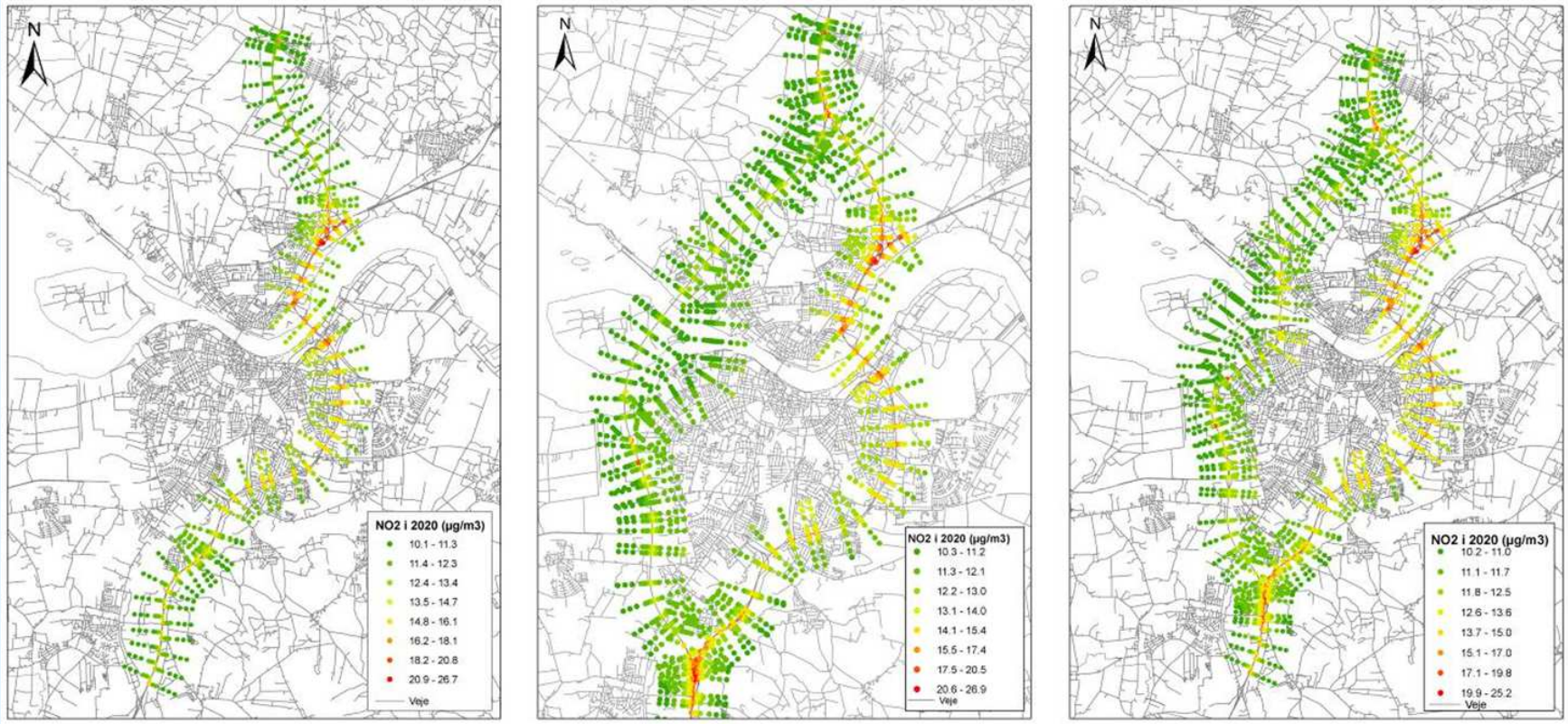
Treatment of tunnels in OML-HW

› **Treated as addition al line source at tunnel opening**





Receptor points along motorways



- **Receptor points up to 1,000 m from motorway**
- **Residential addresses joined to nearest receptor point**

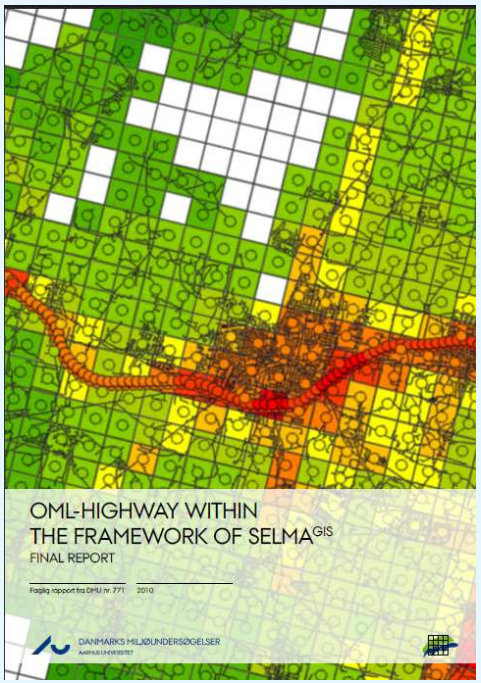
Conclusion

- **OML-Highway model is a user-friendly GIS-based model for assessment of air quality along roads in open terrain**
- **OML-Highway model has been successfully evaluated against measurement datasets from Denmark and Norway for NO_x and NO_2**
  - **more development and model inter-comparison exercises**
- **Lessons from new Danish Validation dataset (preliminary)**
  - **OK for the 150 m location**
  - **Up-wind dispersion missing for the near road location (effect of trees / cut / traffic turbulence) → combine OML-Highway + OSPM**
  - **Traffic / emission variation needs refinement**
- **Openair toolbox is very helpful**

Acknowledgement

- **Funding**
  - Danish Road Directorate has financed OML-Highway model development and EIA applications

- **Report in English**
  - Jensen, S.S., Becker, T., Ketzel, M., Løfstrøm, P., Olesen, H.R., Lorentz, H. (2010): OML-Highway within the framework of SELMAGIS. 26 p, NERI Technical Report No. 771. http://www.dmu.dk/Pub/FR771.pdf.
- **Validation article**
  - Berger, J., S. E. Walker, B. Denby, R. Berkowicz, P. Løfstrøm, M. Ketzel, J. Härkönen, J. Nikmo and A. Karppinen, 2010. Evaluation and inter-comparison of open road line source models currently in use in the Nordic countries, Boreal Env. Res., 15.



Thank you for your attention