H14-104: Improvement of a simple dispersion model for calculations of urban background concentrations

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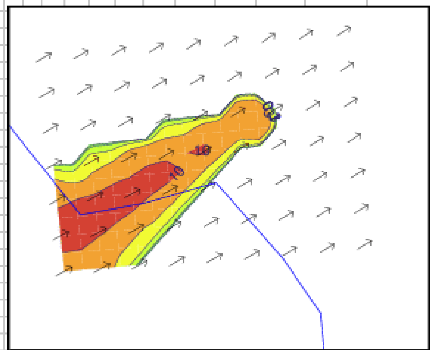
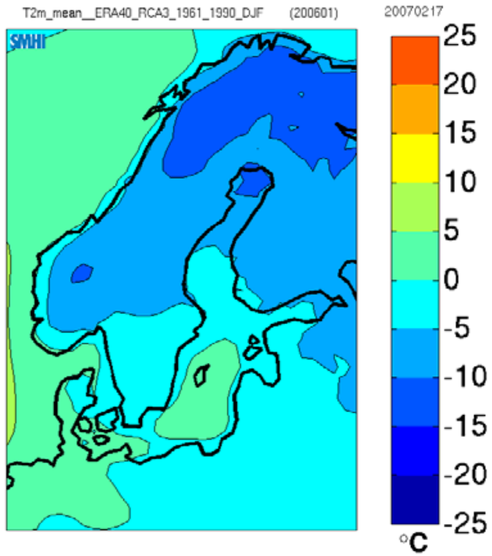


Outline

- ➔ ***Motivation***
- ➔ ***Model description***
- ➔ ***Improvements***
- ➔ ***Validation against measurements***

Cold weather conditions in Sweden affect the Air Quailty

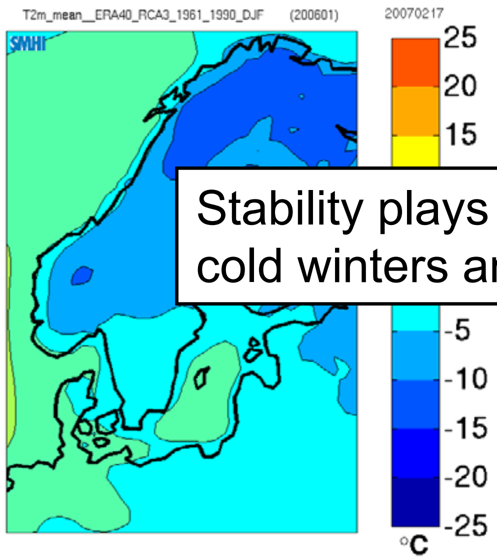


Mean temperarue below 0°C in winter

Slippery roads and need of anti-skid treatment
➔ road wear and resuspension of road dust

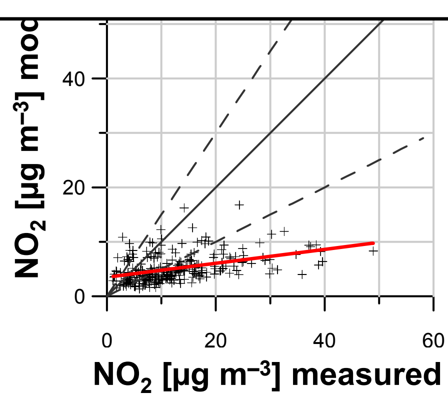
Need of heating
➔ emissions from residential wood combustion

Cold weather conditions in Sweden affect the Air Quailty



Mean temperarue below 0°C in winter

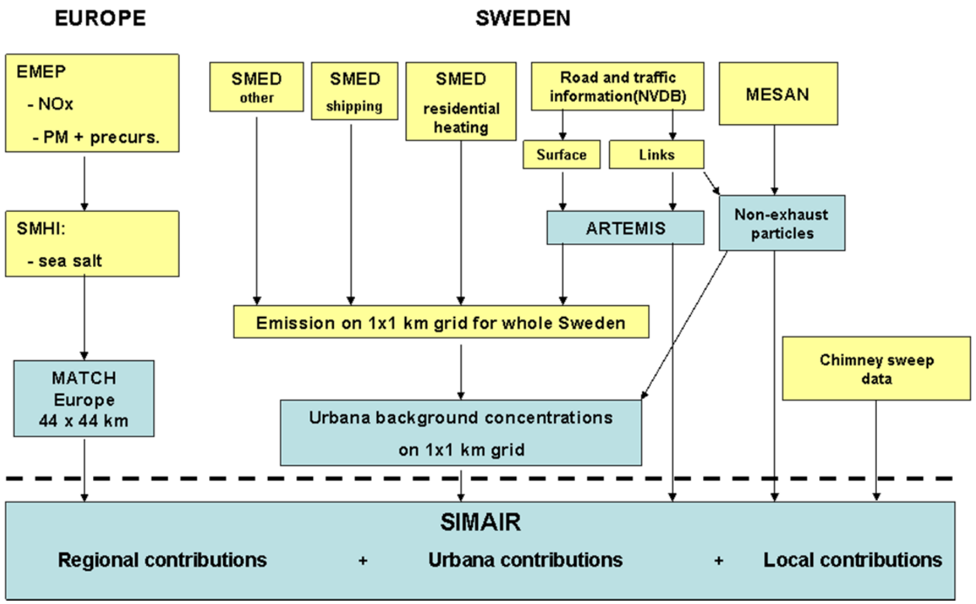
Stability plays an important role for Swedish conditions with cold winters and small towns.



Urban background:
NO_2 daily mean values [µg m^{-3}] for Luleå in northern Sweden, year 2006.

Difficulties for models to reproduce the highest concentration peaks

The Swedish national web based Air Quality model system SIMAIR



- Tool for evaluation of compliance with EU Air Quality Directive.
- Can be used by all Swedish municipalities to calculate air pollution levels.
- Coupled model system, with databases and dispersion models on regional, urban and local scale.
- Emission data from EMEP, SMED and ARTEMIS.
- Meteorological data from the routine objective analysis system Mesan.
- Yearly updates

References:

- Omstedt, G., Andersson, S., Gidhagen, L. and Robertson, L., 2011: Evaluation of new model tools for meeting the targets of the EU Air Quality Directive: A case study on the studded tyre use in Sweden. Accepted for publication in International Journal of Environment and Pollution.
- Gidhagen, L., Johansson, H. and Omstedt, G., 2009: SIMAIR - Evaluation tool for meeting the EU directive on air pollution limits. Atmospheric Environment, 43, 1029-1036, doi:10.1016/j.atmosenv.2008.01.056.

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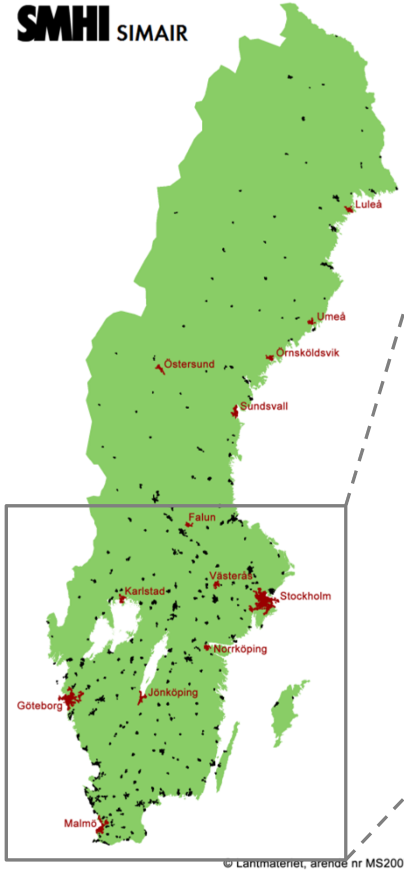

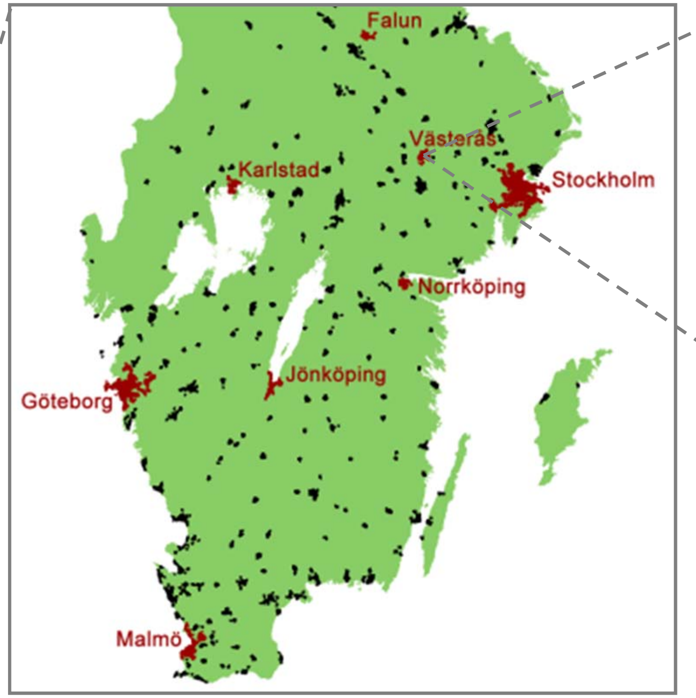

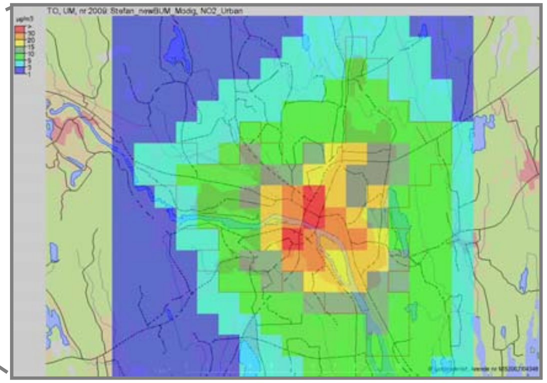

The model system is applied for more than 150 Swedish cities and towns.

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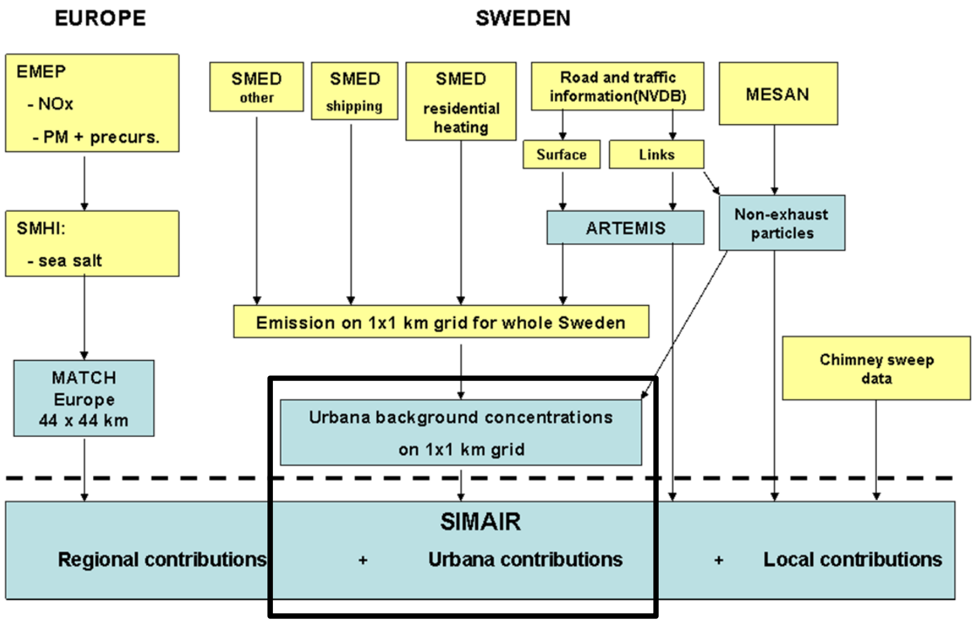

In this study, the model calculating urban background contributions, is improved.

References:

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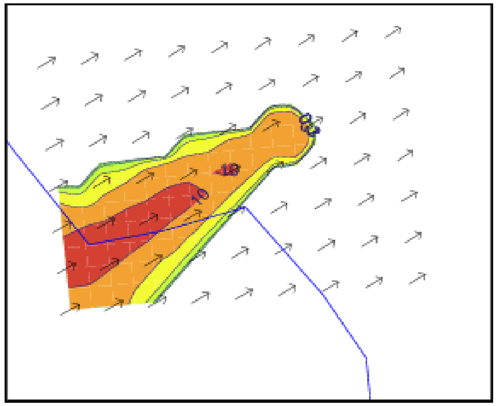
Model description of SWE-BUM



$$\begin{cases} C = \dfrac{1}{2\Delta\theta} \displaystyle\int_{-\Delta\theta}^{\Delta\theta} \int_{0}^{x} f(\theta) \dfrac{Q(x,\theta)}{u\sigma_z(x)} dx d\theta \\ f(\theta) = sin\left(\pi \dfrac{\Delta\theta + \theta}{2\Delta\theta}\right) \end{cases}$$

$$\Delta\theta = \max\left(\frac{0.5}{u}; 0.25\right)$$

$$\sigma_z(x) = h_0 + (h_{mix} - h_0)(1 - e^{-\frac{\sigma_w \cdot x}{u(h_{mix} - h_0)}})$$

SWE-BUM

- Model for urban background contributions.
- Contributions from ground-level emission sources are calculated by a simple trajectory model using an adjoint approach, similar to the model developed for Copenhagen (Berkowicz, 2000).
- Spatial resolution: 1 km x 1 km
- Temporal resolution: 1h

Reference:

- Berkowicz, R., 2000: A simple model for urban background pollution. Environment Monitoring and Assessement, Vol. 65, pp.259–267.

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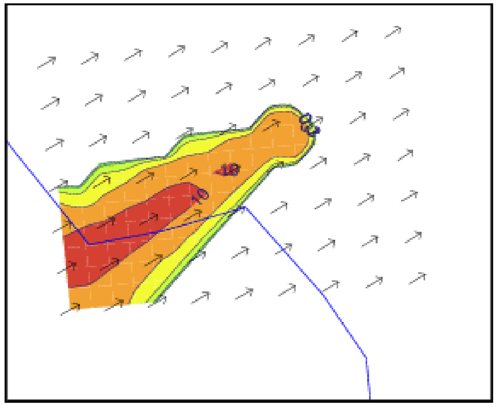

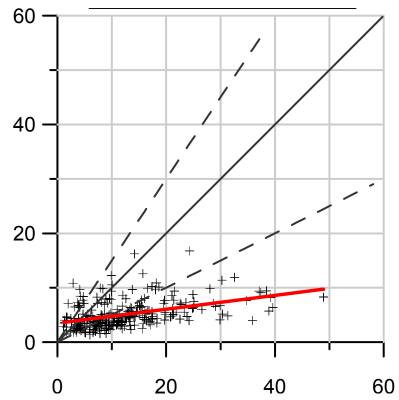

Urban background:
NO_2 daily mean values [µg m^{-3}] for Luleå in northern Sweden, year 2006.

However, the model seems to underestimate the concentrations in comparison with measurements in Sweden.

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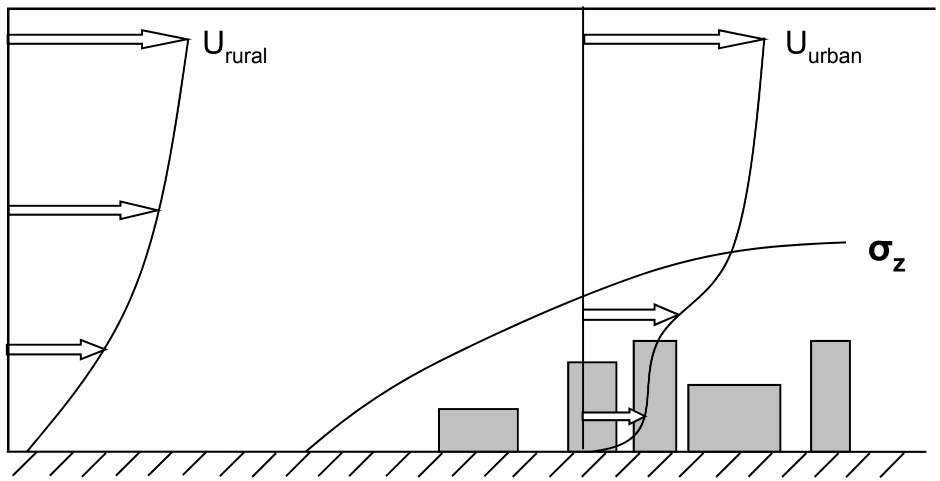
Improvements:
correction of meteorology to represent urban conditions

$$u(z)_{urban} = \frac{u_{*urban}}{k}\left(\ln\left(\frac{z}{z_{0\,urban}}\right) - \Psi_m\left(\frac{z}{L_{urban}}\right) + \Psi_m\left(\frac{z_{0\,urban}}{L_{urban}}\right)\right)$$

- The meteorology in the routine objective analysis system (Mesan) can be regarded as respresenting rural conditions.
- Hence, it is important to adopt a correction of the meteorology to represent urban conditions.
- This is done by means of Monin-Obukov's similarity theory.



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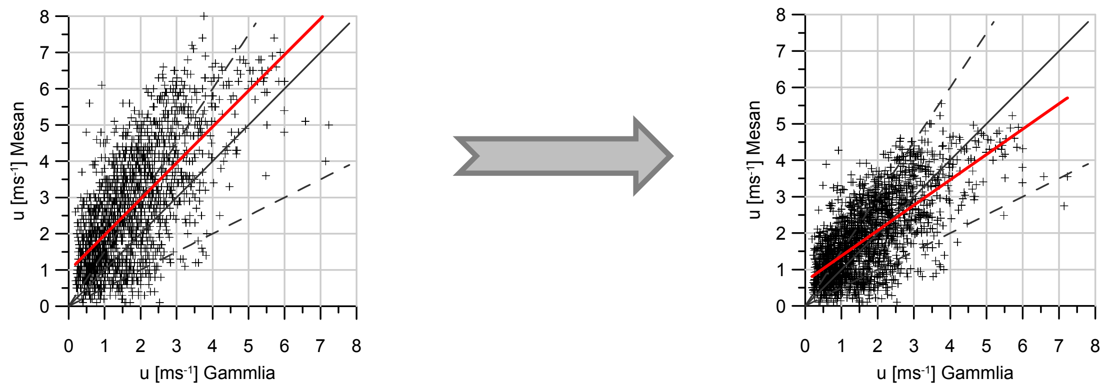

The effects of implementing a correction of meteorology according to above. Example for a town in northern Sweden (Umeå), where Mesan and corrected wind speeds are compered with measurements.

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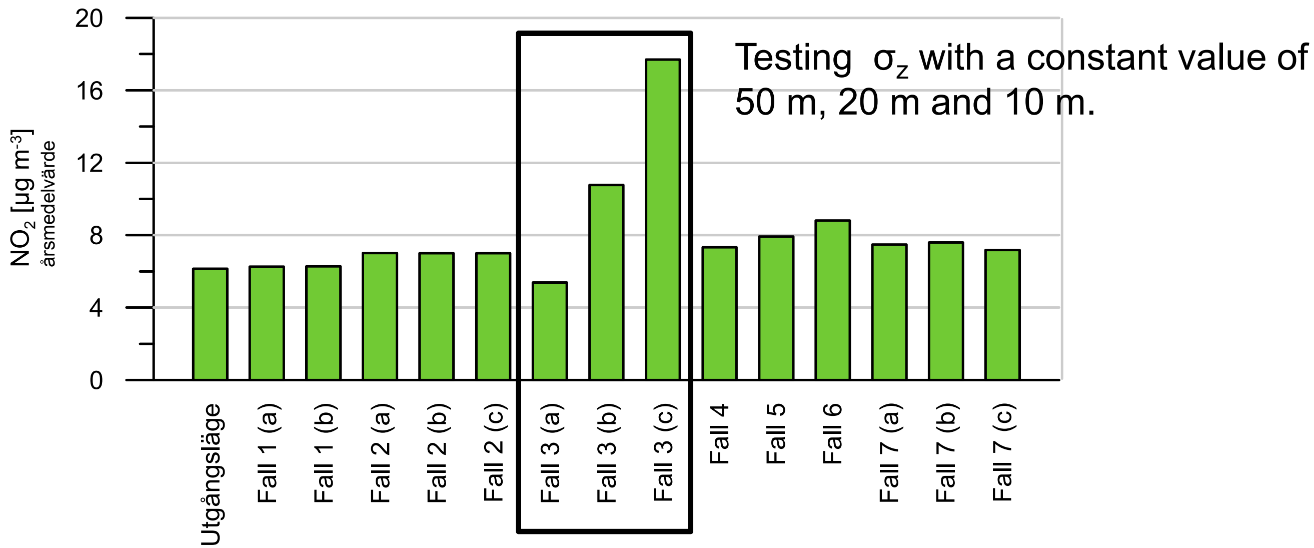
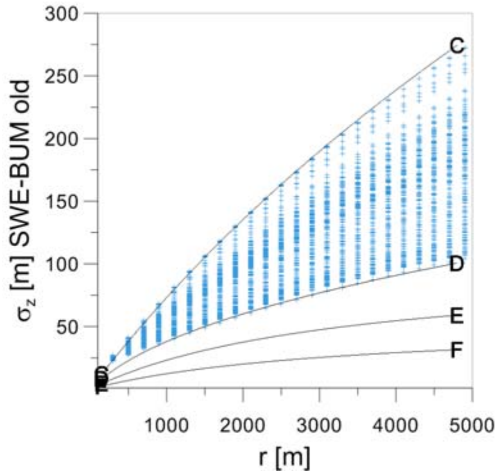
Improvements:
a simple stability parameterisation of σ_z



A sensitivity study has been carried out

- The vertical dispersion parameter σ_z is the most important parameter affecting the concentrations of NO_2.

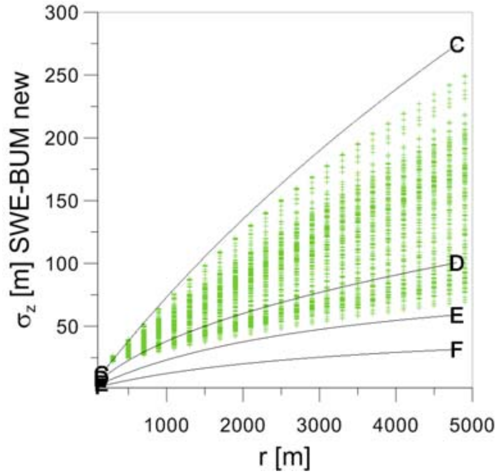
Improvements:
a simple stability parameterisation of σ_z



$$\sigma_z(x) = h_0 + (h_{mix} - h_0)\left(1 - e^{-\frac{\beta \cdot \sigma_w \cdot x}{u(h_{mix} - h_0)}}\right)$$

Variation of σ_z with distance

- It is rather similar to Brigg's formulas for open county conditions (see curves C-F).
- However, for a winter month in a town in northern Sweden, more stable conditions are expected.

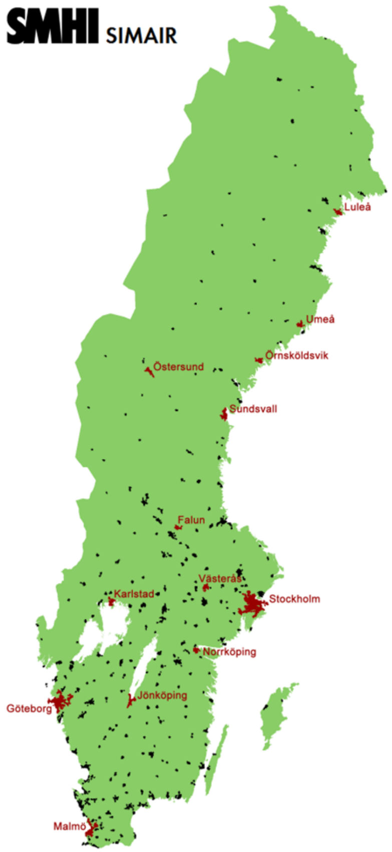


A simple stability parameterisation is introduced

$$L \leq 0 \quad \beta = 1$$

$$L > 0 \quad \beta = \frac{1}{1 + \frac{20z}{L}}$$

Validation against measurements



Monitoring stations

- The model has been validated against NO_2 measurement data, for 13 urban background stations in different parts of Sweden.
- The measurements have been carried out by the municipalities.

City	Station name	Location	Instrument type	Measuring period
Malmö	Rådhuset	Rooftop	Active	2005, calendar year
Jönköping	Hoppets torg	3 m above ground	Passive	2005, winter half-year
Göteborg	Femman	Rooftop	Active	2005, calendar year
Norrköping	Rosen	Rooftop	DOAS	2005, calendar year
Stockholm	T. Knutssonsg.	Rooftop	Active	2005, calendar year
Karlstad	Rådhuset	3 m above ground	Passive	2005, winter half-year
Västerås	Stadshuset	Rooftop	DOAS	2005, calendar year
Falun	Folkets hus	Rooftop	DOAS	2005, calendar year
Sundsvall	Stadshuset	Rooftop	DOAS	2005, calendar year
Östersund	Z-gränd	3 m above ground	Passive	2005, winter half-year
Örnsköldsvik	Centrum	3 m above ground	Passive	2005, winter half-year
Umeå	Stadsbiblioteket	Rooftop	Active	2004, 2005, 2007, calendar year
Luleå	Stadshuset	Rooftop	DOAS	2006, calendar year

Monitoring data available at the hosting of Air Quality in Sweden:
http://www.ivl.se/tjanster/datavardskap/luftkvalitet

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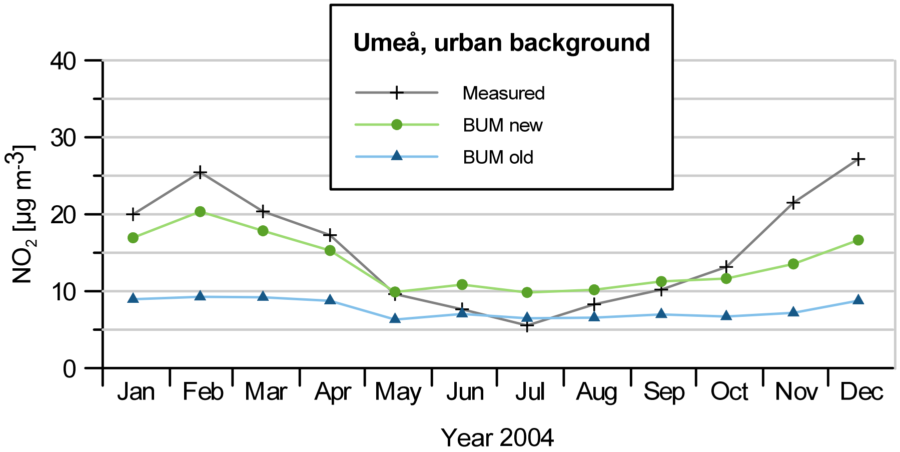
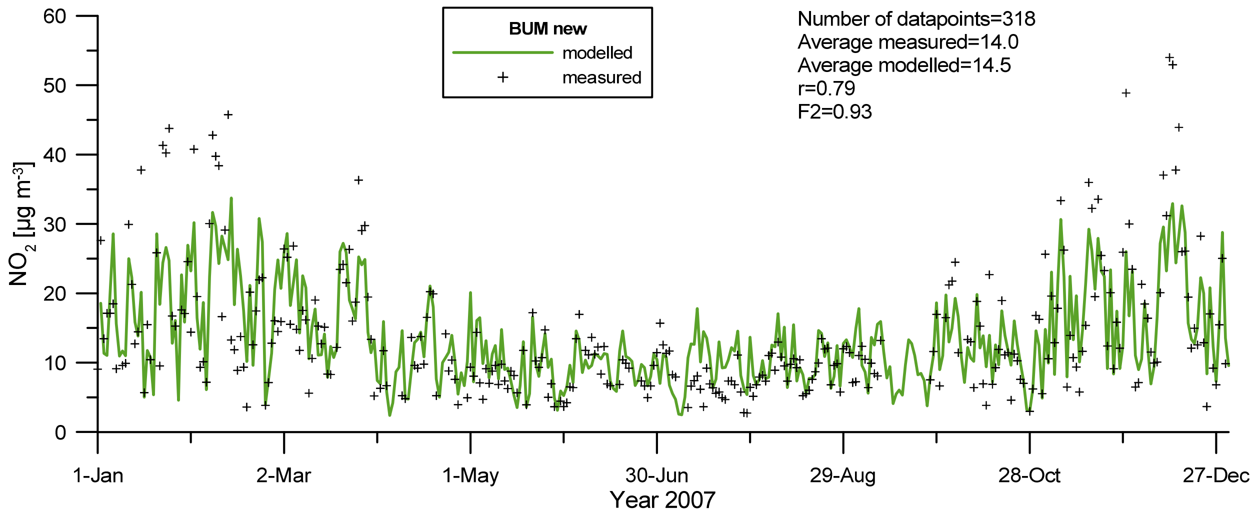
Validation against measurements

Example for Umeå in northern Sweden

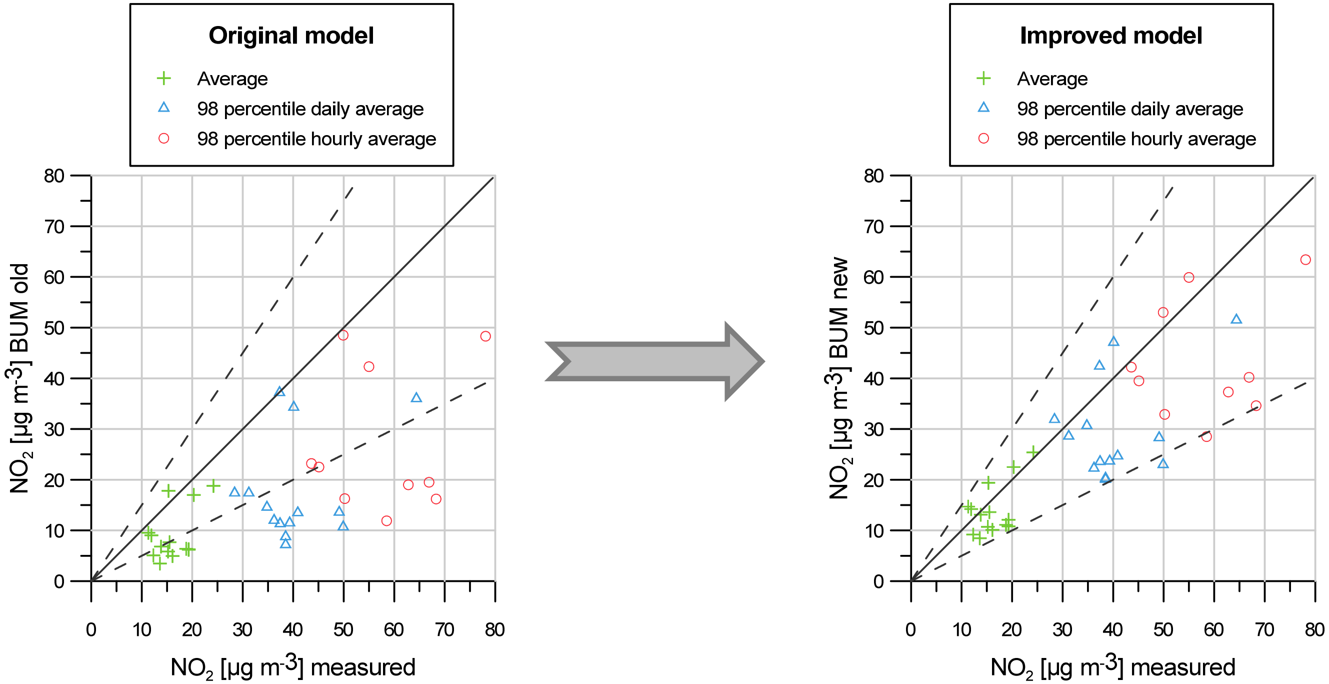


Time variation

- The seasonal variation is much better captured in the new model version.
- The correlation increases.
- However, the highest concentration peaks are still not fully reproduced in the model.



Validation against measurements



FACT2 = 41 %

FACT2 = 95 %

Scatterplots

- The new model is able to reproduce better NO_2 annual average values and 98 percentiles of daily and hourly average.
- 95 % of the data points are within a factor of 2 for the improved model, in comparison with 41 % for the original model.

Validation against measurements

		NO_2 annual average		NO_2 98 percentile daily average		NO_2 98 percentile hourly average	
		old	new	org	new	old	new
RPE	max	0.69	0.41	0.79	0.48	0.76	0.49
	median	0.55	0.27	0.67	0.33	0.59	0.27
RDE	max	0.33	0.19	0.81	0.54	0.79	0.44
	median	0.19	0.08	0.63	0.34	0.64	0.39

Comparison with the quality objectives in the EU Air Quality Directive

- The new model yields improved performance, both in terms of Relative Directive Error (RDE) and Relative Percentile Error (RPE).
- RDE values lower than RPE for annual average, reflecting the fact that the concentrations in general are far below the EU AQ standards for NO_2 annual average.

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Thank you for your attention!