_____

EXTENDED ABSTRACT

Modelling NO2 concentrations around the city of Utrecht (the Netherlands) with uEMEP: comparison with measurements and Dutch monitoring results.

S. C. (Shelley) van der Graaf [1] (email: shelley.van.der.graaf@rivm.nl)
P. Witsenboer [1], J. Wesseling [1], E. van der Swaluw [1]

[1]*National Institute for Public Health and the Environment (RIVM), the Netherlands*

Introduction and methods

Nitrogen dioxide (NO_2) is a highly reactive atmospheric trace gas that is primarily emitted by mobile and industrial fossil-fuel combustion. Once emitted, NO_2 contributes to tropospheric ozone and aerosol formation, having negative consequences on human and ecosystem health and climate. To monitor NO_2 levels in the atmosphere and formulate and keep track of the effectiveness of air quality measures, accurate air quality monitoring tools are of utmost importance.

Since 2009, the Dutch public authorities have been working together to improve air quality through the National Air Quality Cooperation Programme (NSL). In the context of the NSL, local authorities collected information on traffic situations on the main highways and roads. This information was used in an air quality management and monitoring tool (NSL monitor) to, among other things, check whether the Netherlands complies with European limit values. To assure the quality of the calculated NO_2 concentrations of the NSL monitor, extensive regional measurement networks were set up in and around several Dutch cities.

The results of the NSL monitor, which are *specifically* designed for the Netherlands, present a unique opportunity to evaluate another, independent modelling system: the urban EMEP (uEMEP) model (Denby et al., 2020). The uEMEP model is an air quality downscaling model based on Gaussian modelling principles, which, in this study, is embedded in the EMEP4NL model (i.e., the Dutch configuration of the EMEP MSC-W (European Monitoring and Evaluation Programme Meteorological Synthesising Centre West) Eulerian grid model. uEMEP is more *generally* designed for urban modelling over the European domain, and can be used to model NO_2/NO_x concentrations for relatively large regions on a very high spatial resolution (up to ~10 meters)

In this study, we evaluated modelled NO_2 concentrations from uEMEP in and around the city of Utrecht, the Netherlands, for the year 2019. This evaluation is twofold: First, the modelled NO_2 concentrations from uEMEP were compared to the available measurements. Second, after a calibration of the background, the modelled NO_2 concentrations from uEMEP were compared to the results of the NSL monitor at all measurement locations. An overview of the model domain and the available measurements is given in Figure 1.
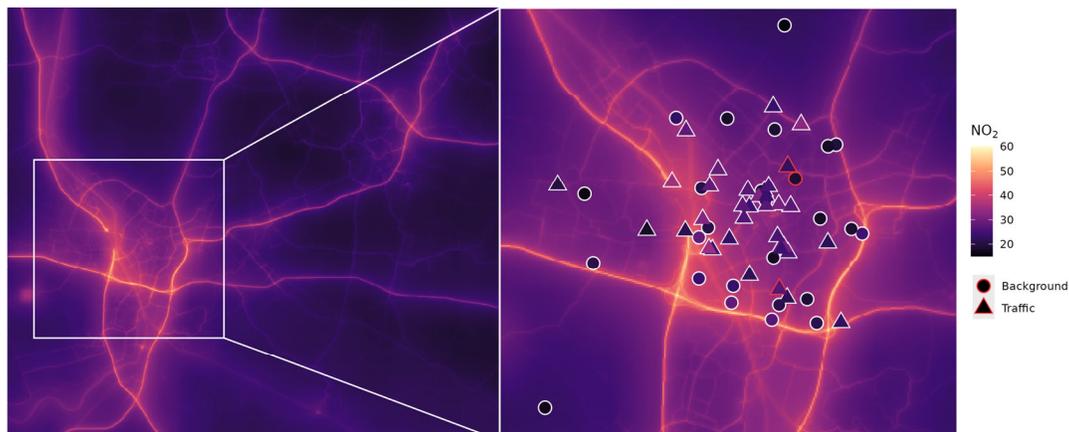
Figure 1. An overview of the uEMEP model domain and measurement locations used for model evaluation. The stations with the white outlines are monthly passive sampler measurements from the regional network, the "Utrechts Meetnet". The red outlines represent hourly measurements of the Dutch national air quality network, the "Landelijk Meetnet Luchtkwaliteit". The colours represent the mean modelled and observed NO_2 concentrations in 2019.

Results: Comparison with measurements

The modelled NO_2 concentrations from uEMEP and EMEP4NL were compared to hourly (LML) and monthly passive samplers (Utrechts Meetnet) measurements.
The uEMEP results showed a larger root-mean-squared error (RMSE) and positive bias to the hourly measured NO_2 concentrations than the results from EMEP4NL. The modelled NO_2 concentrations from uEMEP, on the other hand, showed higher correlations with measurements compared to EMEP4NL, especially at traffic influenced sites (Figure 2). Comparing the annual mean NO_2 concentrations (Table 1), uEMEP also showed a clear improvement in correlations to measurements compared to EMEP4NL. Furthermore, modelled NO_2 concentrations from EMEP4NL were overestimated compared to measurements. As a result, the modelled NO_2 concentrations from uEMEP were also overestimated. To mitigate this effect, the non-local part of the modelled NO_2 concentrations from uEMEP (which is based on the non-local fractions from EMEP4NL) was calibrated based on the comparison at two regional background sites. After calibration, we found an improved comparison with measurements (i.e., lower RMSE and bias) for uEMEP calculations.

Table 1. An overview of statistics between the measured annual mean NO_2 concentrations (N=63) in and around the city of Utrecht and the corresponding modelled NO_2 concentrations from EMEP4NL and uEMEP.

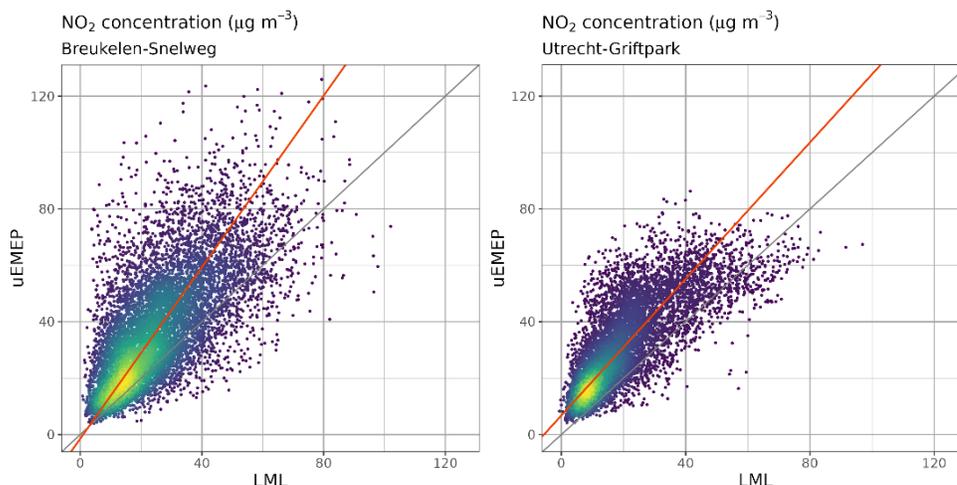|	RMSE	Bias	Intercept	Slope	r
EMEP4NL	**5.17**	**2.42**	22.34	0.14	0.28
uEMEP	12.59	11.69	**9.90**	**1.08**	**0.53**

Figure 2. Scatter plots of the measured and modelled hourly NO$_2$ concentrations at LML sites Breukelen-Snelweg (traffic, left) and Utrecht-Griftpark (urban background, right) in 2019.
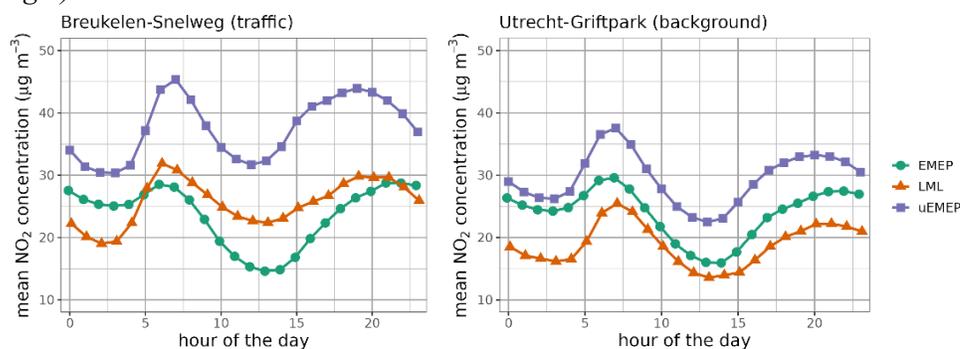

Figure 3. The diurnal cycles of measured and modelled hourly NO$_2$ concentrations at LML sites Breukelen-Snelweg (left) and Utrecht-Griftpark (right) in 2019. (Here, EMEP is EMEP4NL).

Results: Comparison with Dutch monitoring results (NSL-monitor)

After calibration of uEMEP, the annual mean modelled NO$_2$ concentrations were again compared to the measurements, and to the results of the NSL monitor as well (Figure 4). Overall, both models seemed to overestimate the annual mean NO$_2$ concentrations. We found a moderate correlation (r=0.54) for uEMEP. The comparison between measurements and calculations from the NSL-monitor, on the other hand, yields a stronger correlation (r=0.82).

The direct comparison between the modelled NO$_2$ concentrations from uEMEP (after calibration) and the NSL monitor at the measurement sites showed a moderate correlation (r=0.56) between the two models (Figure 5). The modelled NO$_2$ concentrations from uEMEP were ~20% higher than those of the NSL monitor. Here, we observed two distinct clusters. Firstly, there seemed to be a higher correlation at

(mostly) urban and rural background sites (r=0.85). At these locations, the modelled NO_2 concentrations from uEMEP were slightly higher than those of the NSL monitor. Secondly, at the traffic-influenced sites, there seemed to be a cluster with lower correlations, where uEMEP generally underestimates the NO_2 concentrations. Here, the NSL monitor performs better.
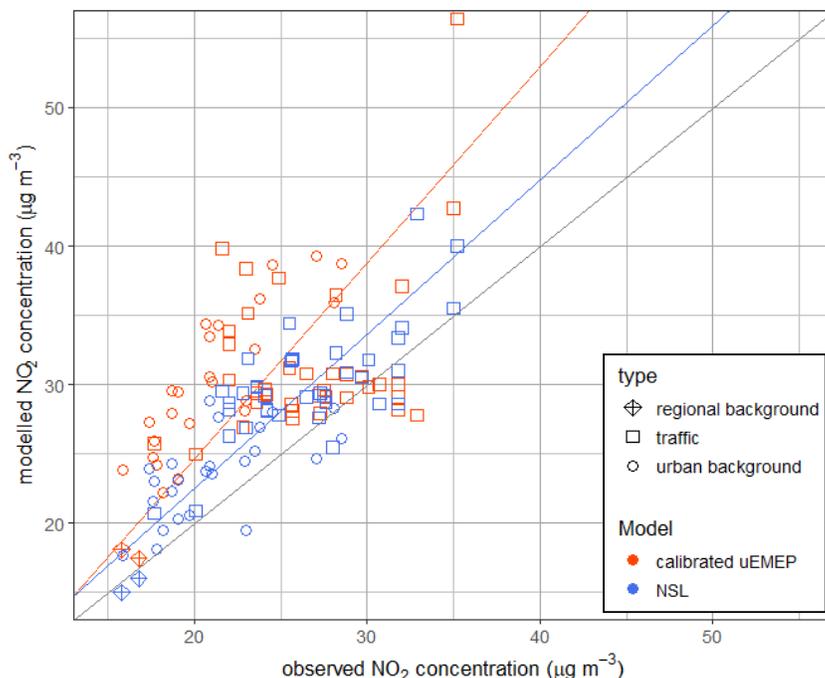

Figure 4. The measured NO_2 concentrations versus the modelled NO_2 concentrations from the NSL-monitor (blue) and the uEMEP model after calibration (red).

Discussion and outlook

Accurate air quality monitoring tools are of utmost importance for monitoring NO_2 levels in the atmosphere and keeping track of the effectiveness of air quality measures. In this study, results from the uEMEP model were evaluated with measurements and results from the NSL monitor, another monitoring tool specifically designed for the Netherlands.

The comparison with measurements illustrated that uEMEP can effectively model NO_2 concentrations at high spatial resolution in urban areas. Generally, an improved correlation to measurements was found compared to calculations from EMEP4NL, whose model runs are performed at a much coarser resolution. To correct for regionally overestimated background NO_2 levels originating from the EMEP4NL model runs, however, calibration of the non-local fractions from EMEP4NL may be necessary.

The comparison with NSL monitor showed a moderate correlation between uEMEP and NSL monitor at the measurement sites. However, two distinct clusters were visible. We found higher correlations at urban and regional background sites, and lower correlations at traffic influences sites. This distinction suggested that uEMEP is less representative

in case of street canyon effects, which is not surprising due to the lack of a sub-model for that. This effect, on the other hand, seemed to be captured better in the NSL monitor, which uses a differentiation between different dispersion models (SRM-1 and SRM-2) depending on the type of road.

In urban areas, the turbulence and dispersion of emissions are influenced heavily by obstacles (e.g., buildings, sound barriers, etc.). As a result, emissions may, for instance, disperse more in a vertical sense before mixing horizontally, which would make the initial dispersion parameters that are assumed in uEMEP less representative here. To improve modelled NO_2 local fractions from traffic in uEMEP, we therefore suggest including a routine that differentiates between different types of traffic emissions and roads. For example, emissions characteristics (e.g., initial dispersion, emission height) could for instance be varied per type of road. Another suggestion would be to include more different traffic subsectors with distinct emission characteristics.
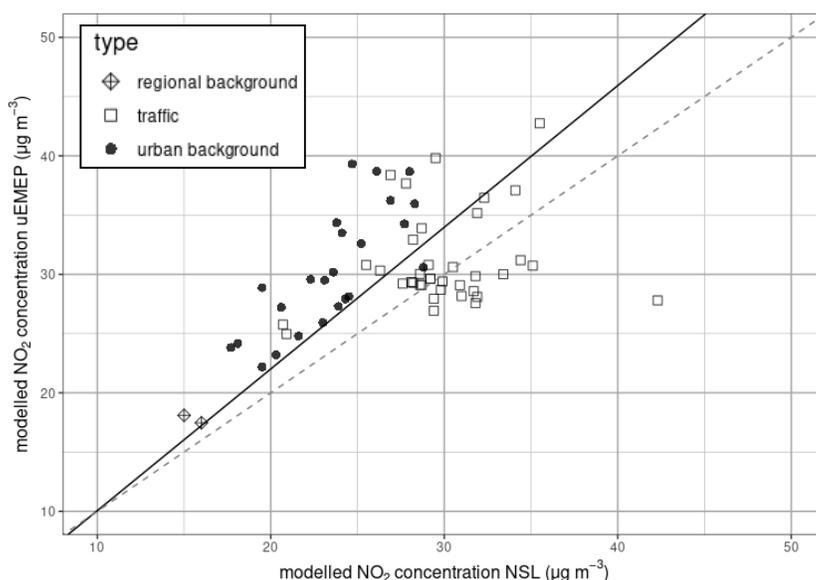

Figure 5. The modelled NO_2 concentrations from the NSL monitor versus the modelled NO_2 concentrations of the uEMEP model (after calibration) at the measurement sites. The different symbols indicate different types of measurement sites.

References

Denby, B. R., Gauss, M., Wind, P., Mu, Q., Grøtting Wærsted, E., Fagerli, H., Valdebenito, A., and Klein, H.: Description of the uEMEP_v5 downscaling approach for the EMEP MSC-W chemistry transport model, Geosci. Model Dev., 13, 6303–6323, https://doi.org/10.5194/gmd-13-6303-2020, 2020.

Van der Graaf, S., Witsenboer, P., Wesseling, J., and van der Swaluw, E.: Modelling NO_2 concentrations in urban areas with uEMEP: evaluation with measurements and NSL monitoring results around the city of Utrecht for the year 2019, RIVM Knowledge brief KN-2024-0074, doi: 10.21945/RIVM-KN-2024-0074, 2025.