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OML-HIGHWAY - A ROAD SOURCE MODEL IN A GIS ENVIRONMENT - EVALUATION WITH MEASUREMENTS

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Abstract: OML-Highway is a road source dispersion model recently developed by the National Environmental Research Institute (NERI) in Denmark, based on the well established OML model. It is a local-scale Gaussian air pollution model based on boundary layer scaling, which estimates dispersion from point and area sources. Road sources are approximated as area sources. The parameterisation for the initial dispersion is based on the formulation in the OSPM model, but is slightly modified with regard to the characteristics of highways. In OML-Highway traffic produced turbulent kinetic energy is not assumed constant as in the OSPM model but decays in an exponential manner with distance from the road. OML-Highway has been integrated into the GIS environment SELMA^{GIS} by Lohmeyer GmbH & Co. KG, which runs as an extension to ArcGIS. The implementation of OML-Highway into GIS reduces the risk of mistakes and also reduces substantially the time for preparation of input data. Here we show the implementation of the OML model into OML-Highway and how this approach enables the user to visualise and evaluate input and calculation results at each step of the calculation procedure in a simple and comprehensive way.

Key words: *GIS integrated air pollution model,*

INTRODUCTION

In 2007 NERI elaborated specifications for a user-friendly air pollution model, designed to approximate air pollution along roads in open areas. It was the aim to create a tool for the assessment and mapping of air pollution along these roads. The project was conducted on behalf of the Danish Road Directorate and comprised a measurement campaign of air quality at a specific location on a Danish highway and the implementation of OML-Highway into ArcGIS to provide a user-friendly interface (Wang *et al.*; 2010, Jensen *et al.*, 2010).

OML-Highway is a local-scale Gaussian air pollution model specially designed to describe the dispersion of air pollutants along roads with an open roadside environment (Jensen *et al.*, 2004). It is based on the OML model (Olesen *et al.*, 2007) which is designed for air quality assessment based on point sources. OML-Highway estimates dispersion from point and area sources. OML-Highway requires processed meteorological data, which can be provided by the OML meteorological preprocessor. This preprocessor calculates turbulence parameters based on, e.g., synoptic data, and a special version has been prepared for use with OML-Highway. In OML-Highaway, road sources are approximated as area sources. The parameterisation for the initial dispersion is based on the formulation in the OSPM model (Berkowicz, R., 2000), but is slightly modified with regard to highways. In OML-Highway traffic produced turbulent kinetic energy (TPT) is not assumed constant as in the OSPM model but decays in an exponential manner with distance from the road. OML-Highway has been successfully evaluated against datasets from Denmark and Norway for the pollutant NO_x (= $NO+NO_2$) and it has also been compared to other similar models (Berger *et al.*, 2010).

Here we describe how OML-Highway was integrated into SELMA^{GIS}, a GIS environment developed by Lohmeyer GmbH & Co. KG, Germany (Lorentz, H. and Düring, I., 2008). The purpose of SELMA^{GIS} is to integrate sophisticated dispersion models into a framework with the capability to prepare input data and analyse model output by utilising the spatial capabilities of a GIS. Furthermore, we describe potential application of OML-Highway and elaborate two examples. The first example illustrates the model output along a part of a Danish highway, whereas the second shows the effect of a noise barrier with respect to the dispersion of air pollutants.

METHODS

The challenge was to combine the already existing OML-Highway with a GIS to succesfully construct a user friendly interface. SELMA^{GIS} is capable of handling point and line sources as well as polygons, and it runs as extension in ArcGIS. We decided to use SELMA^{GIS} because it already includes standard models and additional tools for data input, output and visualisation.

The foundation for the programming of the graphical user interface (GUI) was the elaboration of a detailed data flow model that comprised the graphical interfaces as well as the structure of input and output data and also temporal data.

In combination with the development of the GUI and the modules relevant for data preparation it was necessary to implement an interface to the emission module of the Operational Street Pollution Model (OSPM). The emission module utilised in OSPM is based on the emission model COPERT4. OSPM is a model to estimate air quality in street canyons and is developed by NERI.

Furthermore, two additional features are implemented in OML-Highway. Firstly, it is possible to aggregate traffic emissions from a digital road network into a user-defined grid (e.g. 1km x 1km). This feature is used to aggregate emissions from smaller roads that are further away from the area of specific interest to fewer area emission sources in order to reduce calculation times. Secondly, an algorithm has been implemented for the approximation of the influence of noise barriers with respect to the dispersion of air pollutants.

Within the project we conducted an additional evaluation of OML-Highway against a new Danish dataset that apart from NO_x also includes $PM_{2.5}$, PM_{10} and particle number measurements. Emission factors are initially taken from urban situations where on-road emission factors have previously been estimated (Wang *et al.*, 2010), and these are adapted to highway conditions.

RESULTS

The implementation of OML-Highway into SELMA^{GIS} was done in such a way that the user can be guided by a wizard, and at any time has full control over all input data. All data specified by the user can be displayed and edited using the GUI of OML-Highway and the associated programs. Using the functionality of the GIS the user can create various input data (e.g. background grid data, receptor files) via the GUI in a simple and comprehensive way. Also, existing data that do not fit the required data format can be converted into a readable format for OML-Highway. As an example, the user can convert synoptic meteorological data into the appropriate meteorological file including all boundary layer parameters used by OML-Highway.

The GUI of OML-Highway consists of 13 dialogs to setup the process and handle all the data required during the run of OML-Highway.

In the following we present possible applications for OML-Highway.

- Environmental Impact Assessment

  One element of an environmental impact assessment is to provide information to the public about the potential impacts of proposed new highways and describe possible mitigating measures to reduce impacts. This has to be done for various routing alternatives. With OML-Highway information is available about air pollutant concentrations, human exposure and relation to air quality limit values.

- EU Ambient Air Quality Limit Values

  According to EU directive on air quality (EC, 2008) it is a legal obligation for member states to act in response to violations of limit values. OML-Highway can be used to assess past and future air quality levels along highways ordinary roads with respect to EU air quality limit values.

- Systematic Mapping of Air Quality and Human Exposure

  OML-Highway can be used for systematic mapping of air quality and human exposure along the entire state road network and herewith provide an important overview over the current state of air quality and human exposure along the road network. Such information helps in identifying hot spots that merit further analysis and in assessment of mitigation measures.

- "What if" Scenario Analysis

  An emission module is implemented into OML-Highway to predict scenarios of future air quality levels for comparison with air quality limit values in the future. OML-Highway provides full control over the road parameters and vehicle fleet composition. Furthermore OML-Highway is able to take noise barriers into account and is therefore able to model the impact of such mitigation measures. Thus, OML-Highway can answer “what if” questions related to changes in: alternative line routings, road layout (e.g. width of carriageway), traffic volume, vehicle composition, speed and emissions. This makes it a powerful tool for environmental impact assessment and mitigation analysis.

- Ranking of Road Investments based on Cost-benefit Analysis

  The Danish Road Directorate ranks future road construction investments based on cost-benefit principles. Emissions are one of the parameters that are included. A new highway air pollution model that includes air quality and human exposure may further improve these estimates. It was neither within the scope of the OML-Highway implementation project to provide input to the ranking investment procedure nor to improve the present emission methodology to an air quality and exposure methodology, but such outcome might be a potential spin-off in a long term perspective.

Mapping former County of Roskilde (example 1)

The spatial extent of the former county of Roskilde, Denmark with a buffer of eight kilometres was used in an example to calculate air pollution concentration along highway 21 (highlighted in Figure 1, left side). Traffic counts on the motorway are from 2005. Except from highway 21 all other streets are considered as background roads aggregated into area emission sources (1km x 1km). In Figure 1 an extended background grid is shown based on the road network with a mesh size of 1000 meters.

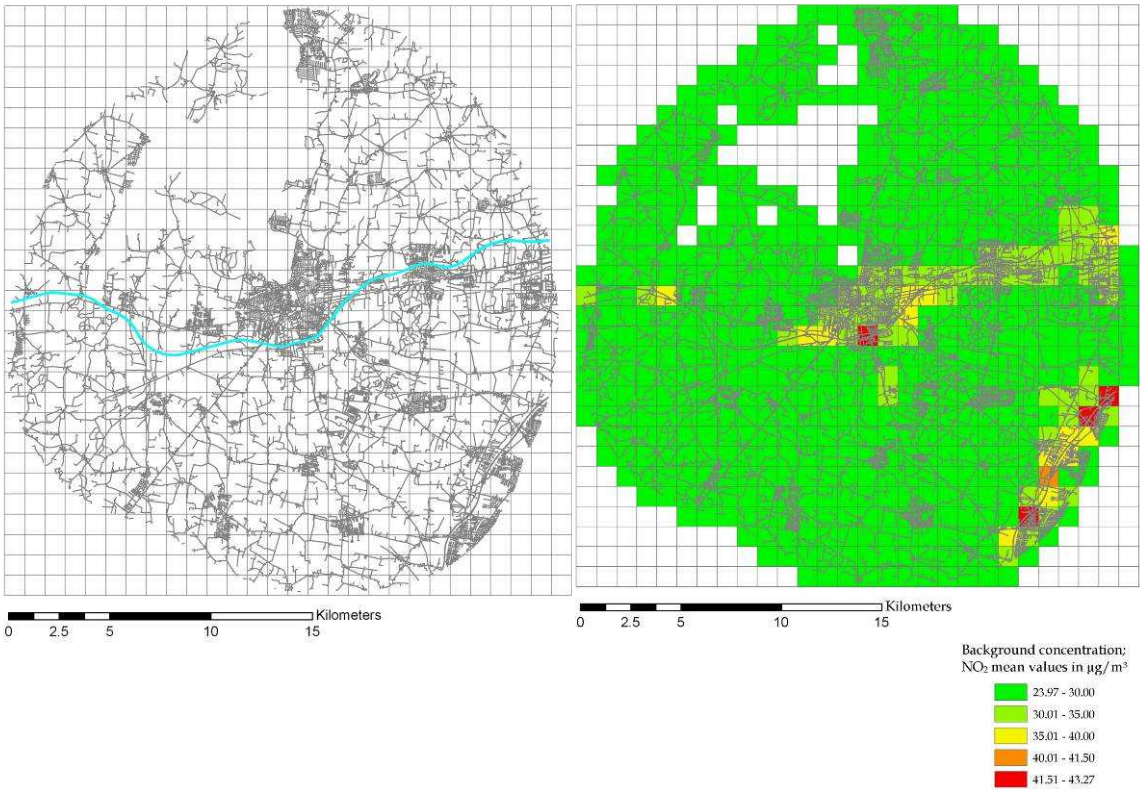

Figure 1. **Left**: Road network of the county of Roskilde and vicinity; highway 21 is highlighted and set as target road; background grid with a cell size of 1000 meter. **Right:** Road network with calculated background concentrations; Receptor points for the background concentrations were placed at the centre of the background grid cells.

On the right side of Figure 1 the background concentrations of NO_2 with an overlay of the road network are presented. In this figure the contribution of two highways (highway 21 in the centre and highway E20 at the lower right edge) to the concentration of NO_2 is visible by elevated NO_2 values.

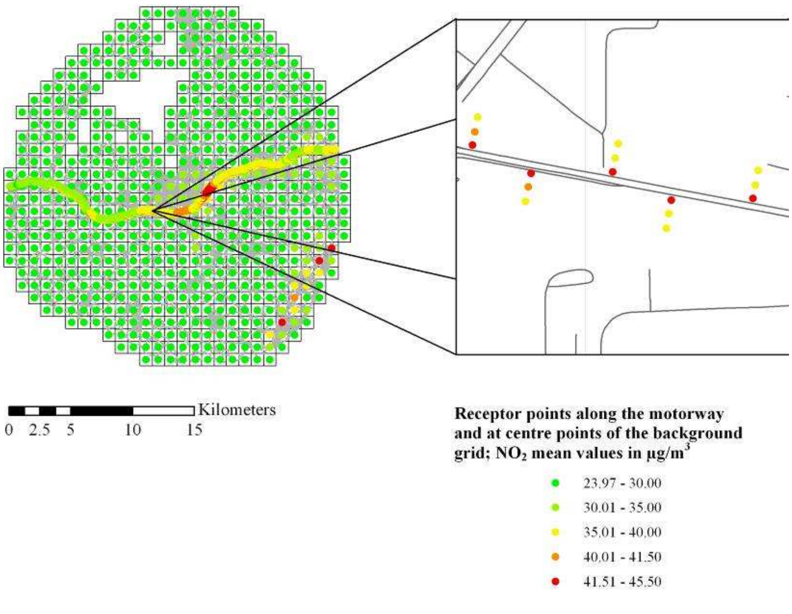

Figure 2. Calculated concentrations at receptor points along the road at a distance of 50 m, 100 m and 200 m from the road on the right side, background values in combination with concentrations along the road on the left side.

Another possibility to visualise model calculations for the background grid is shown in Figure 2. Here, only the centre points of the background grid are shown with a color-coded concentration level, indicating an almost homogeneous concentration field. Along both highways the concentration level is elevated. While highway 21 was flagged as target road and additional receptor points have been assigned along the motorway, the effects of highway E20 are striking also within the receptor points for the background grid. However, due to the very dense receptor points along highway 21 the influence of alternating traffic volume or average speed on every segment of the highway is recognisable.

Detailed case with noise barriers for EIA (example 2)

In OML-Highway it is possible to model the influence of noise barriers and embankments in relation to air pollution concentration along roads. The orientation of the road is implemented according to the standard of the OSPM model and the user can define on which side of the road the noise barrier is located. The length of a barrier is defined by the length of the road segment (Figure 3).

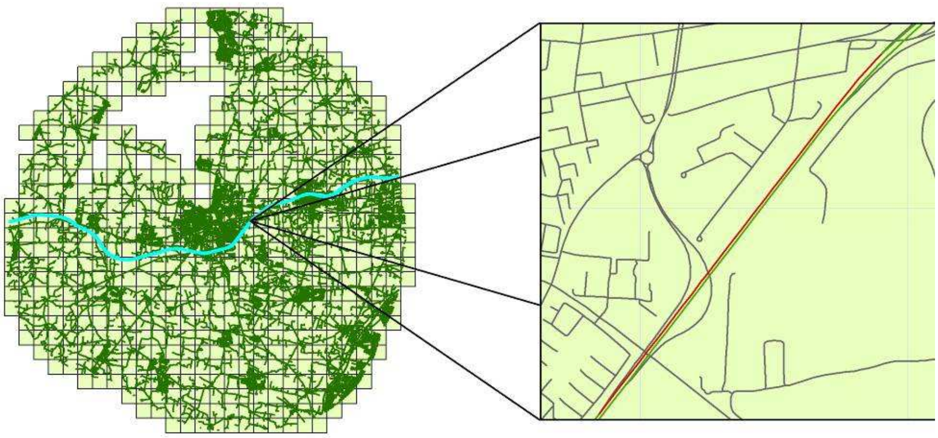

Figure 3. Overview of the location of a fictitious noise barrier along a road segment of highway 21; West of Roskilde on the lane going towards Holbæk, marked in red.

To show the influence of a noise barrier along a road segment on highway 21 a special case was calculated. The setup for this segment includes a calculation without a barrier, with a barrier at a distance of two meters to the road segment and with a height of three meters, and with a noise barrier of six meters height at the same distance to the road segment.

The impact of noise barriers of different heights are shown in Figure 4. The concentrations of NO_2 (left side) and NO_x (right side) close to the road segment are reduced due to the increased turbulence and better dispersion caused by the noise barriers compared to the case without noise barrier. The lowest concentrations are modelled for the noise barrier with a height of 6 meters.

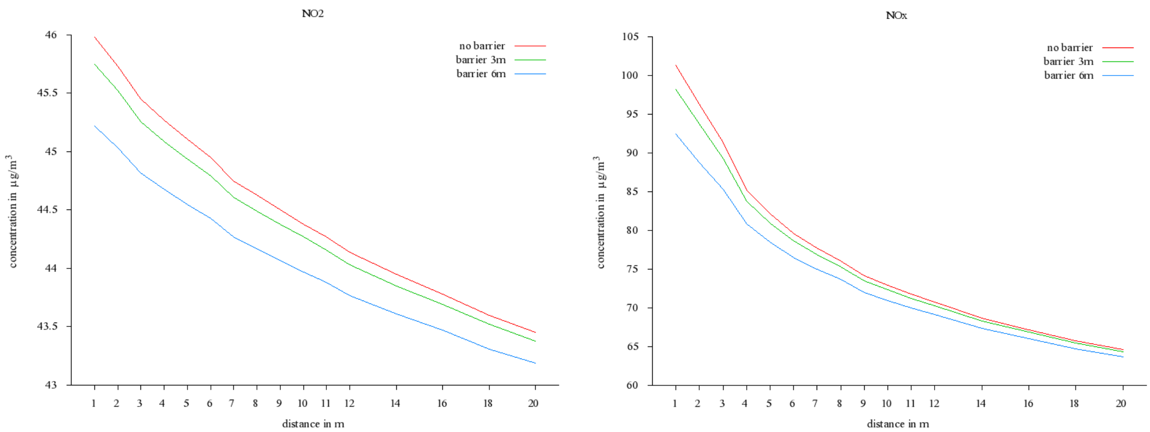

Figure 4. Visualisation of the concentration at 16 receptor points in different distance from highway 21; the plot is showing the effect of noise barriers on the concentration of NO_2 (left side) and NO_x (right side) depending on the distance from the source.

CONCLUSION

A user-friendly GIS-based interface has been constructed to operate OML-Highway and to benefit from the capabilities of the GIS. Utilizing the interface it is possible to estimate air quality along roads with an open roadside environment. Furthermore we identified possible applications for the system and have been illustrating features of the system using the example of a subset of the Danish road network.

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