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

M. Ketzel¹, S.S. Jensen¹, T. Becker¹, H. Lorentz², H.R. Olesen¹ and P. Løfstrøm¹

¹Department of Environmental Science, Aarhus University, Denmark, mke@dmu.dk
²Ingenieurbüro Lohmeyer GmbH & Co. KG, Germany
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 health (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)
  - but decays in an exponential manner with transport time

\[
\sigma_{y,z}^2 = \sigma_{y_0 z_0}^2 + \sigma_{y_0 z_0}^2
\]

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

where \( t \) is the transport time (s), \( \tau \) is the time scale for the decay of TPT (s) and \( \sigma_{\text{initial}} = 3.2 \text{ m} \).
User interface based on SELMA\textsuperscript{GIS}

- SELMAGIS – a tool for modelling and visualisation of air quality data based on ArcGIS\textsuperscript{TM}
- OML-Highway is implemented as an extension in ArcGIS\textsuperscript{TM}
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
  › $\text{NO}_x$, $\text{NO}_2$, $\text{O}_3$, $\text{PM}_{2.5}$ og $\text{PM}_{10}$, particle numbers, CO, and benzene
  › $\text{CO}_2$ 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 models

Fig. 1. Measurement sites. (a) Nordlysletta, 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.

<table>
<thead>
<tr>
<th></th>
<th>HIWAY2-AQ</th>
<th>HIWAY2-AQ</th>
<th>OML-Highway</th>
<th>OML-Highway</th>
<th>OML-Highway</th>
<th>OML-Highway</th>
<th>CAR-FMI</th>
<th>CAR-FMI</th>
<th>CAR-FMI</th>
<th>WORM</th>
<th>WORM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-norm.</td>
<td>0.50</td>
<td>0.18</td>
<td>0.72</td>
<td>0.69</td>
<td>0.50</td>
<td>0.23</td>
<td>0.72</td>
<td>0.42</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q-norm.</td>
<td>0.52</td>
<td>0.21</td>
<td>0.68</td>
<td>0.60</td>
<td>0.48</td>
<td>0.28</td>
<td>0.68</td>
<td>0.47</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-norm.</td>
<td>0.48</td>
<td>0.20</td>
<td>0.62</td>
<td>0.53</td>
<td>0.46</td>
<td>0.37</td>
<td>0.64</td>
<td>0.49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norwegian data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Danish data</td>
<td>0.38</td>
<td>0.18</td>
<td>0.75</td>
<td>0.65</td>
<td>0.49</td>
<td>0.25</td>
<td>0.65</td>
<td>0.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finnish data</td>
<td>0.31</td>
<td>0.27</td>
<td>0.71</td>
<td>0.56</td>
<td>0.43</td>
<td>0.50</td>
<td>0.71</td>
<td>0.43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V4#1</td>
<td>0.51</td>
<td>0.49</td>
<td>–</td>
<td>0.47</td>
<td>0.44</td>
<td>0.51</td>
<td>0.51</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>HIWAY2-AQ</th>
<th>HIWAY2-AQ</th>
<th>OML-Highway</th>
<th>OML-Highway</th>
<th>OML-Highway</th>
<th>OML-Highway</th>
<th>CAR-FMI</th>
<th>CAR-FMI</th>
<th>CAR-FMI</th>
<th>WORM</th>
<th>WORM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-norm.</td>
<td>0.02</td>
<td>-0.16</td>
<td>-0.21</td>
<td>-0.22</td>
<td>-0.11</td>
<td>-0.16</td>
<td>-0.31</td>
<td>-0.34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q-norm.</td>
<td>0.13</td>
<td>-0.07</td>
<td>-0.19</td>
<td>-0.19</td>
<td>0.03</td>
<td>-0.02</td>
<td>-0.28</td>
<td>-0.29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-norm.</td>
<td>0.12</td>
<td>-0.10</td>
<td>-0.20</td>
<td>-0.22</td>
<td>0.18</td>
<td>0.12</td>
<td>-0.24</td>
<td>-0.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norwegian data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Danish data</td>
<td>0.16</td>
<td>-0.27</td>
<td>0.04</td>
<td>-0.18</td>
<td>0.42</td>
<td>0.08</td>
<td>0.11</td>
<td>-0.22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finnish data</td>
<td>0.15</td>
<td>-0.35</td>
<td>0.00</td>
<td>-0.30</td>
<td>0.67</td>
<td>0.24</td>
<td>0.13</td>
<td>-0.26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V4#1</td>
<td>-0.13</td>
<td>-0.14</td>
<td>–</td>
<td>0.09</td>
<td>0.09</td>
<td>-0.48</td>
<td>-0.49</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Validation for $\text{NO}_x$ and $\text{NO}_2$ in 2003

All wind directions

Distance from road (m)

Concentration (ppb)

$\text{NO}_x$

$\text{NO}_2$

(Jensen et al. 2004a,b)
Newer Danish data set (Highway 21)

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


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

More validation plots in ‘openair’

› (‘Hexbin’) Frequency-scatterplots

‘openair’ project
More validation plots in ‘openair’

› Combine statistics and plots as model performance indicators

<table>
<thead>
<tr>
<th>weekday</th>
<th>n</th>
<th>FAC2</th>
<th>MB</th>
<th>MGE</th>
<th>NMB</th>
<th>NMGE</th>
<th>RMSE</th>
<th>r</th>
<th>COE</th>
</tr>
</thead>
<tbody>
<tr>
<td>mandag</td>
<td>208</td>
<td>0.52</td>
<td>-44.9</td>
<td>70</td>
<td>-0.34</td>
<td>0.63</td>
<td>94</td>
<td>0.72</td>
<td>0.244</td>
</tr>
<tr>
<td>tirsdag</td>
<td>211</td>
<td>0.45</td>
<td>-39.1</td>
<td>62</td>
<td>-0.37</td>
<td>0.59</td>
<td>89</td>
<td>0.61</td>
<td>0.152</td>
</tr>
<tr>
<td>onsdag</td>
<td>216</td>
<td>0.43</td>
<td>-22.2</td>
<td>62</td>
<td>-0.20</td>
<td>0.56</td>
<td>90</td>
<td>0.75</td>
<td>0.396</td>
</tr>
<tr>
<td>torsdag</td>
<td>180</td>
<td>0.47</td>
<td>-30.5</td>
<td>65</td>
<td>-0.26</td>
<td>0.56</td>
<td>86</td>
<td>0.66</td>
<td>0.205</td>
</tr>
<tr>
<td>fredag</td>
<td>167</td>
<td>0.57</td>
<td>-38.4</td>
<td>61</td>
<td>-0.28</td>
<td>0.44</td>
<td>78</td>
<td>0.75</td>
<td>0.323</td>
</tr>
<tr>
<td>lørdag</td>
<td>203</td>
<td>0.57</td>
<td>6.2</td>
<td>36</td>
<td>0.10</td>
<td>0.59</td>
<td>47</td>
<td>0.50</td>
<td>0.067</td>
</tr>
<tr>
<td>søndag</td>
<td>216</td>
<td>0.58</td>
<td>8.0</td>
<td>35</td>
<td>0.14</td>
<td>0.60</td>
<td>47</td>
<td>0.40</td>
<td>0.083</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>season</th>
<th>n</th>
<th>FAC2</th>
<th>MB</th>
<th>MGE</th>
<th>NMB</th>
<th>NMGE</th>
<th>RMSE</th>
<th>r</th>
<th>COE</th>
</tr>
</thead>
<tbody>
<tr>
<td>spring (MAM)</td>
<td>1401</td>
<td>0.61</td>
<td>-22</td>
<td>55</td>
<td>-0.22</td>
<td>0.55</td>
<td>78</td>
<td>0.67</td>
<td>0.26</td>
</tr>
</tbody>
</table>
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 additional 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\textsubscript{x} and NO\textsubscript{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


› Validation article

Thank you for your attention