How to determine urban background concentrations from traffic flows in neighbouring street canyons?

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Introduction

• Introduction
• Methodology
  • Emission calculations
  • Air quality modelling
• Results and discussion
• Conclusions
The problem

• A large class of street canyon models use:

\[ C = C_{\text{street}} + C_{\text{background}} \]

➢ The urban background concentration is needed for every single hour in the calculation!

➢ Note that: \( P_{98} \neq P_{98,\text{street}} + P_{98,\text{background}} \)
Solution proposed…

• For every hour calculate:

\[ C = C_{\text{street}} + C_{\text{background}} \]

From a street canyon model (OSPM)

From a Gaussian plume model (IFDM)

Methodology

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HARMO-10, Sissi (Malia), Crete, Greece, 17-20 October, 2005

**OSPM**

**IFDM**

**PARAMICS**

- **meteor-towers**
- **hourly meteo-data**
- **hourly concentrations**
- **hourly background concentrations**
- **Emission functions**
- **hourly traffic emissions**

**Emission functions**

**Traffic emissions**

**IFDM**

**OSPM**

**PARAMICS**

**HARMO-10 Crete 2005**
Emission calculations

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Micro-simulation model
Paramics

• micro-level:
  • vehicles are modelled one by one
  • every time step: new position, speed, acceleration

• input:
  • infrastructure, traffic lights, traffic rules, speed limits,…
  • traffic demand, traffic behaviour

• output:
  • Position, speed and acceleration of the vehicle per time step

Emission-functions as plug-in for Paramics

• Emission functions are based on the extended dataset of VITO's on-the-road-vehicles emission measurements (VOEM) (De Vlieger, 1997).

• During these measurements the vehicle's speed and its instantaneous emissions of CO, CO₂, NOx, HC and PM were recorded at every second

• Emission functions were integrated into Paramics as a plug-in
Paramics output

- Summarized per hour and per square meter of road surface
- X, Y, CO, CO₂, NOx, HC and PM,
- sum of speeds, acceleration & number of cars,
- for each vehicle class (29 classes)
- XML output format
  - quite handy for data exchange
  - 1 Gb / scenario

Postprocessing Paramics output

- From square meter of road surface to meter along street axis
- Line sources for IFDM
- OSPM receptor / street canyon description every 10 m along street axis
- Intermediate results for Quality Control
Averaged vehicle speed

Number of vehicles
Air quality modelling

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IFDM

- Gaussian plume model
- More than 30 years of experience
- Used by a large community of air quality experts (more than 40 licences)
- At present the regulatory impact assessment model in Flanders

In validation exercises and comparisons with other models, IFDM has proven to give excellent results in urban conditions.
Results and discussion

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Results

• Calculations for NO\textsubscript{x} and PM\textsubscript{2.5}
• 3 scenarios:
  • “Current”: European emission standards 2003 & traffic situation 2003
  • “Scenario 1”: European emission standards 2010 & traffic situation 2003
  • “Scenario 2”: European emission standards 2010 & traffic situation 2010
    (local traffic plan)
Local traffic plan

- Drop of speed limits (70 → 50 km/h; 50 → 30 km/h)
- Altering driving direction in 12 one-way streets
- Introducing “sleeping policemen” on 6 intersections
- Downsizing important avenue from 2 x 2 to 2 x 1 lanes
- Constructing two new urban sites (425 productions and attractions in new OD-matrix)

IFDM Background concentrations
(all Paramics emissions)

Average (µg/m³) Gentbrugge per 25m, 2003
Annual averaged PM$_{2.5}$ concentrations in 2003

Relative change in PM$_{2.5}$ (2003-2010)

Red areas (-10%)
Green areas (-70%)
Discussion

- PM$_{2.5}$ concentrations decrease between 2003 and 2010 in every location in the area studied from -10% in less polluted streets to -70% in some of the worst polluted sites of this moment;

- Nearly all of this decrease may be attributed to the more stringent European emission standards for new vehicles;

- Local mobility plans have only little effect compared to the impact of the new European emission standards.
Discussion

• Computational time required to calculate a scenario is limited and in the order of a few minutes: Gaussian approach is very fast.
Static population map: no exposure near highways

Dynamic map: Exposure of PM2.5 per street
Discussion

• Extension of the methodology towards population exposure:
  ➢ Static
  ➢ Dynamic

• Activity based approach for surveying and modelling travel behaviour

• Development of an exposure model for activity based models (PhD)

Conclusions

• We realised a coupling between the street canyon model OSPM and the Gaussian model IFDM.

• Results for a city quarter in Ghent, Belgium, show that the background contribution from a nearby highway exit contributes substantially in streets with low to moderate traffic.

• Decreases in PM$_{2.5}$ concentrations between 10% and 70% are expected between 2003 and 2010, due to more stringent EU emission standards.

• Mobility plans only show a limited effect.
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Next receptor

Next hour of meteorological data

$C_h = 0$

loop over sources

Point / Area / Line sources

IFDM (area)

IFDM (point)

IFDM (line)

$C_h = C_h + C_s$
Next receptor

Next hour of meteorological data

\[ C_h = 0 \]

Loop over sources

Point / Area / Line sources

IFDM (area)

IFDM (point)

IFDM (line)

Street canyon geometry & emission

OSPM

\[ C_h = C_h + C_s \]