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

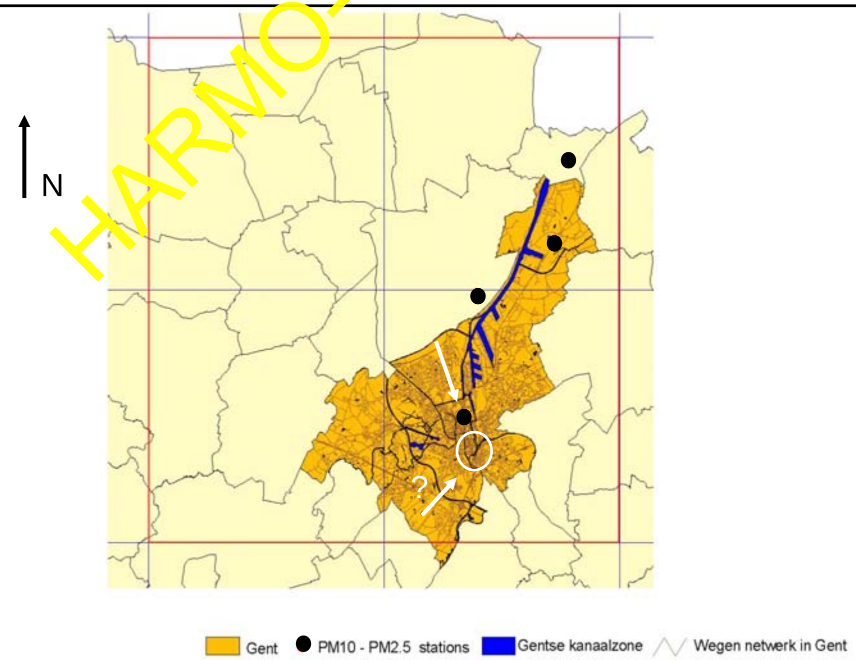
The problem

- A large class of street canyon models use:

$$C = C_{street} + C_{background}$$

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

➢ Note that: $P_{98} \neq P_{98,street} + P_{98,background}$



Solution proposed…

- For every hour calculate:

$$C = C_{street} + C_{background}$$

From a street canyon model (OSPM)

From a Gaussian plume model (IFDM)

Methodology

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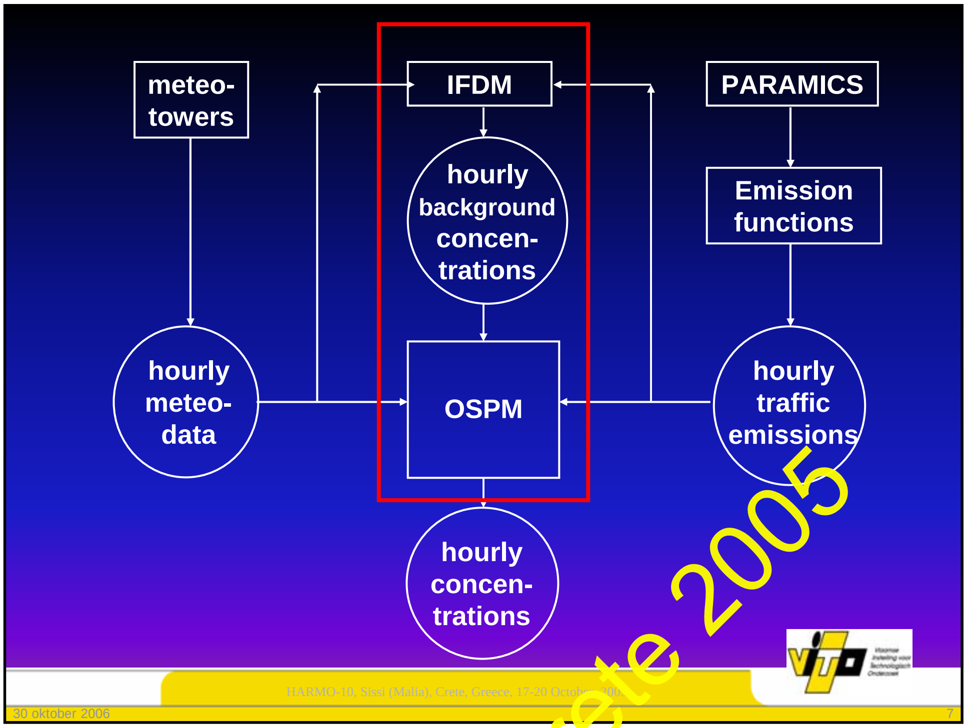
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IFDM
PARAMICS
hourly
background
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Emission
functions
hourly
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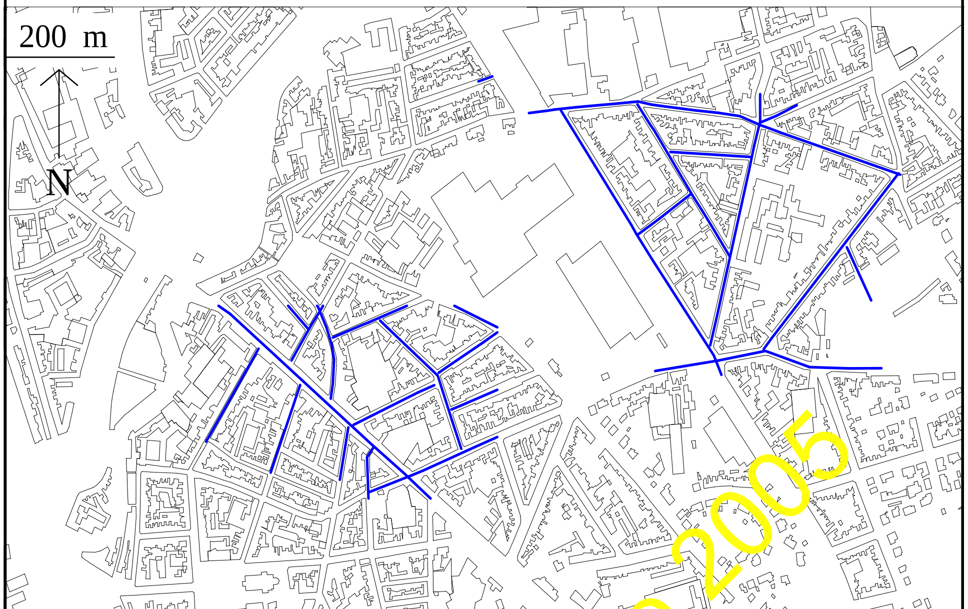
EMI-Graph @ Vito-Mol

Mobile



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
- ouput:
  - 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, CO_2, NOx, HC and PM were recorded at every second
- Emission functions were integrated into Paramics as a plug_in

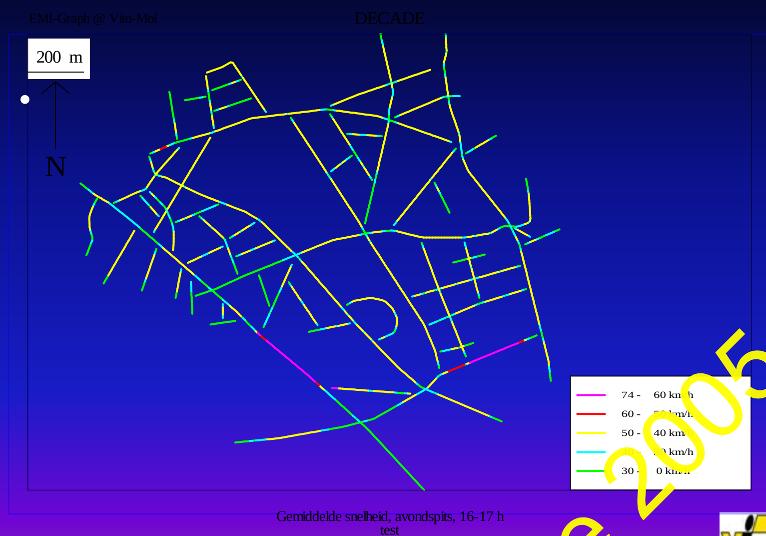
Paramics output

- Summarized per hour and per square meter of road surface
- X, Y, CO, CO_2, 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

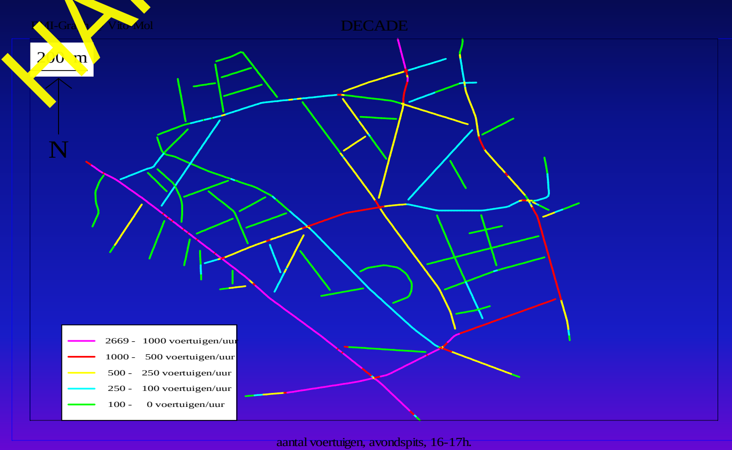
Postprocessing Paramics output

- 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



NO_X-emissions (per 5 meter)

Air quality modelling

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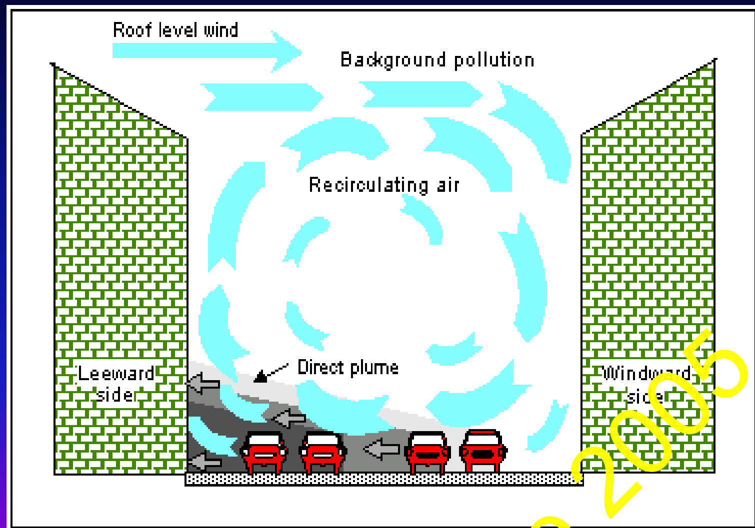
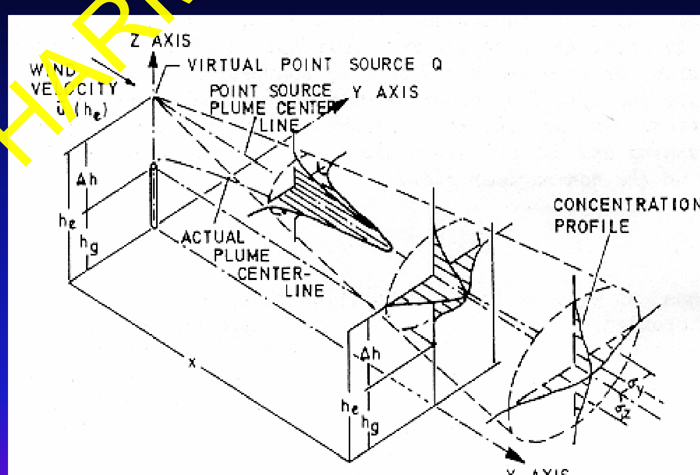
OSPM: street canyon model



IFDM



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

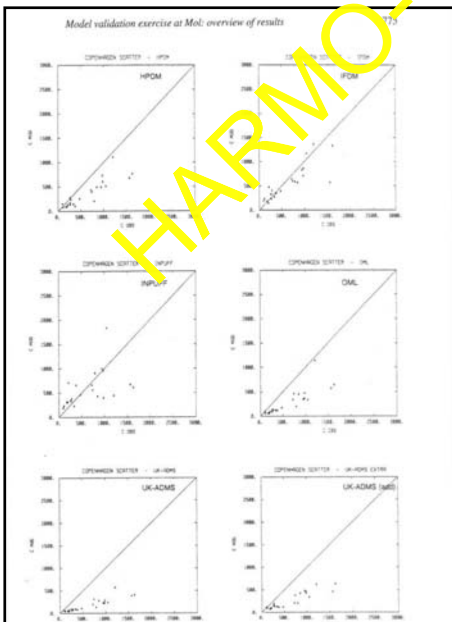


Figure 8 Copenhagen dataset: scatter plot of normalized concentrations; concentration unit, 10^{-9} s/m^3.

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

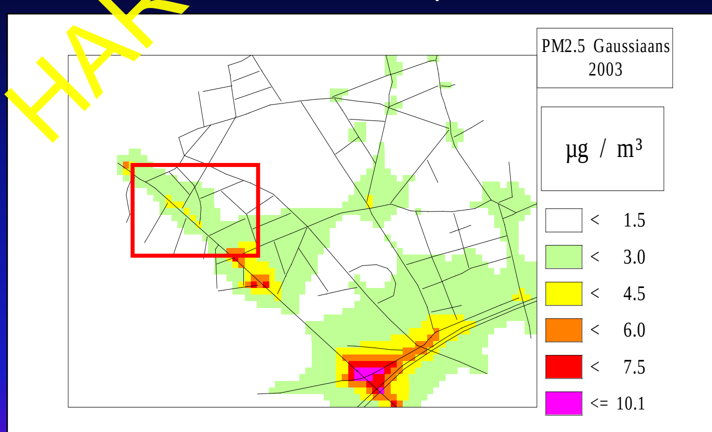
- Calculations for NO_x and $PM_{2.5}$
- 3 scenarios:
  - "Current": European emission standards 2003 & traffic situation 2003
  - "Scenario 1": European emission standards 2010 & traffic situation 2003
  - "Scenario 2": European emission standards 2010 & traffic situation 2010 (local traffic plan)

Local traffic plan

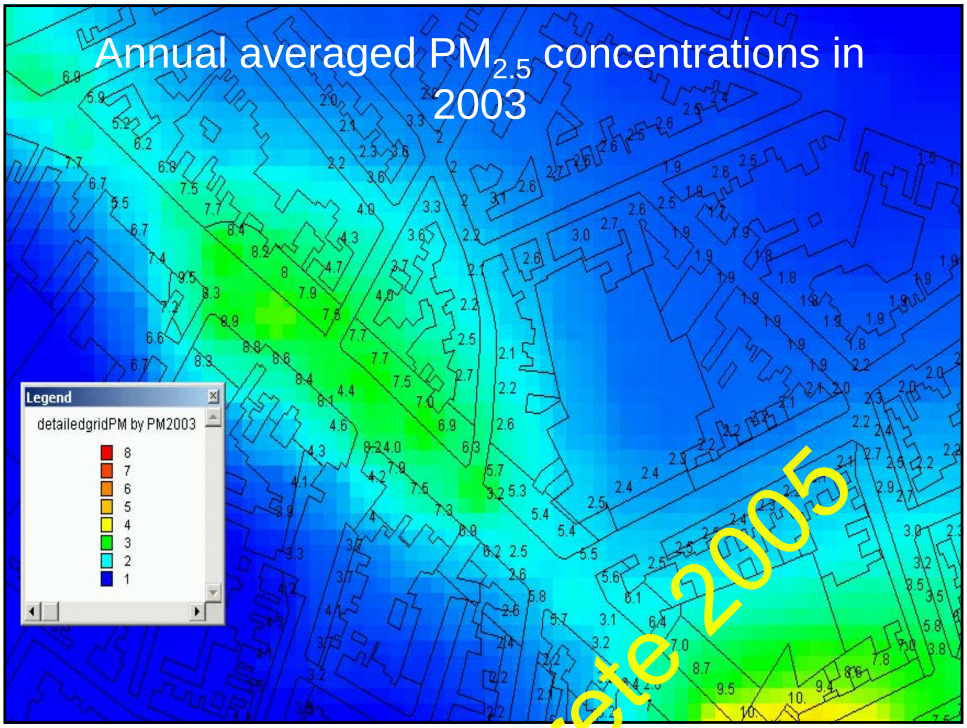
- Drop of speed limits (70 → 50 km/h; 50 → 30 km/h)
- Altering driving direction in 12 one-way streets
- Introducing “sleeping policemen” on 6 intersections
- Downsizing important avenue from 2 x 2 to 2 x 1 lanes
- Constructing two new urban sites (425 productions and attractions in new OD-matrix)

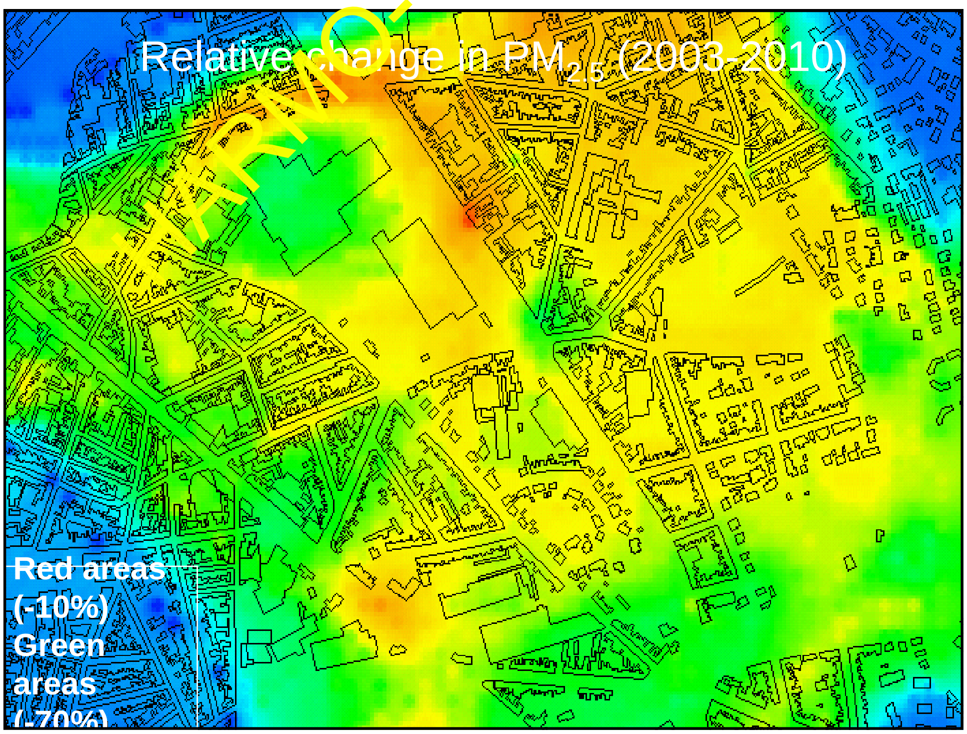
IFDM Background concentrations

(all Paramics emissions)

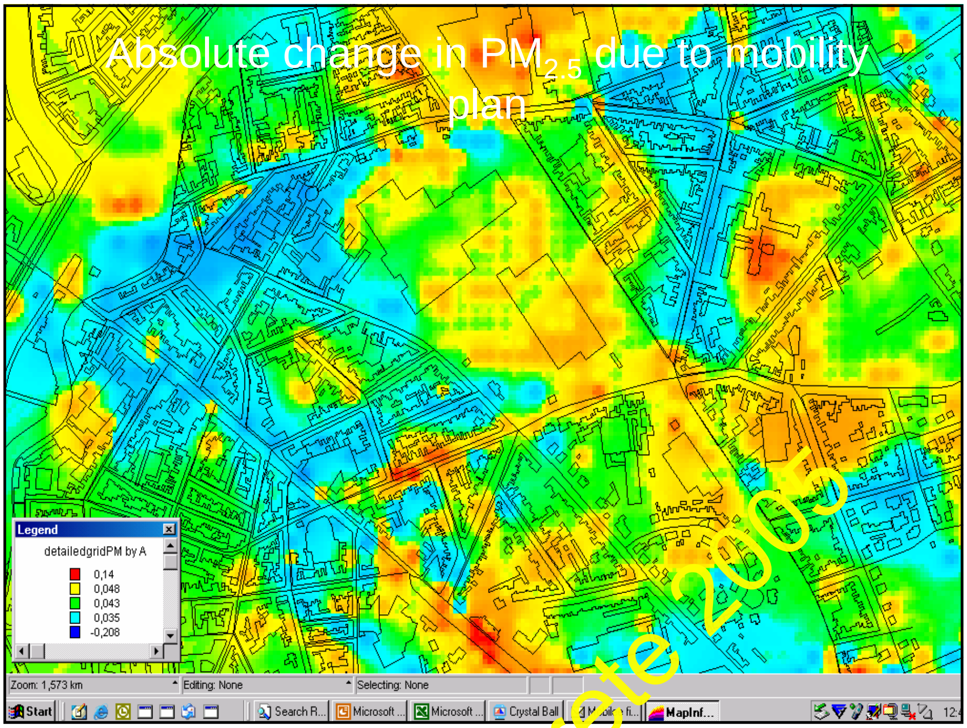


Average (µg/m³) Gentbrugge per 25m , 2003


Annual averaged $PM_{2.5}$ concentrations in 2003
Legend
detailedgridPM by PM2003
8
7
6
5
4
3
2
1


Relative change in $PM_{2.5}$ (2003-2010)
Red areas (-10%)
Green areas (-70%)

Absolute change in $PM_{2.5}$ due to mobility plan



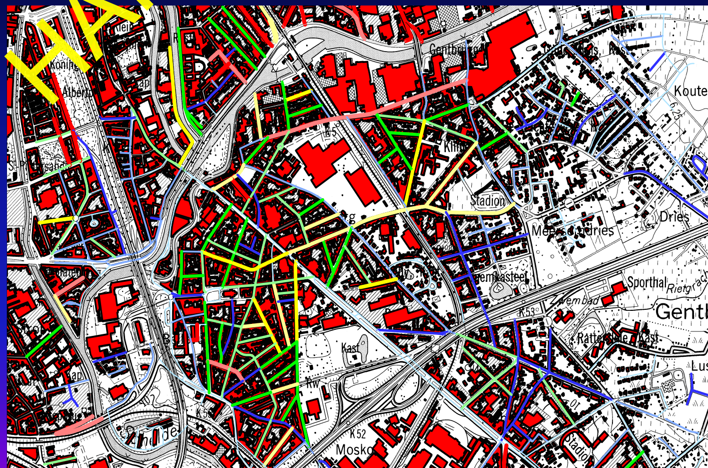
Discussion

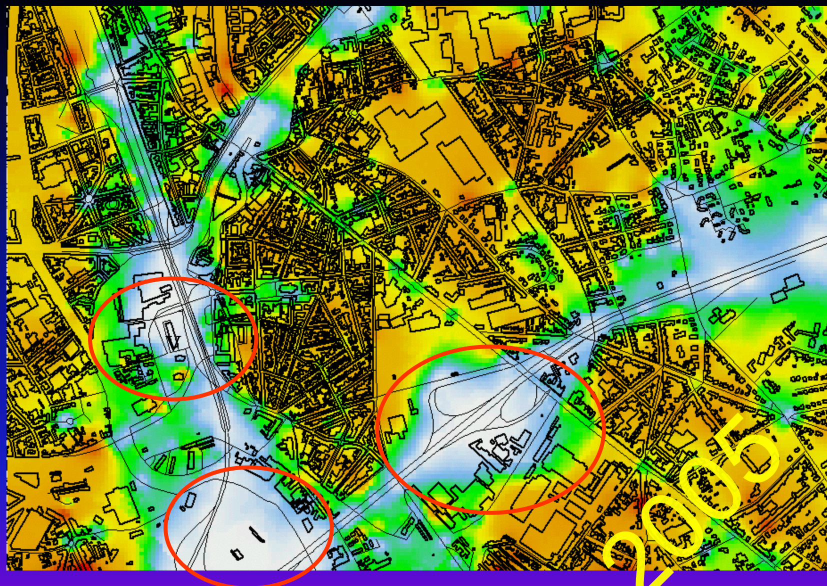
- $PM_{2.5}$ concentrations decrease between 2003 and 2010 in every location in the area studied from -10% in less polluted streets to -70% in some of the worst polluted sites of this moment;
- Nearly all of this decrease may be attributed to the more stringent European emission standards for new vehicles;
- Local mobility plans have only little effect compared to the impact of the new European emission standards.

Discussion

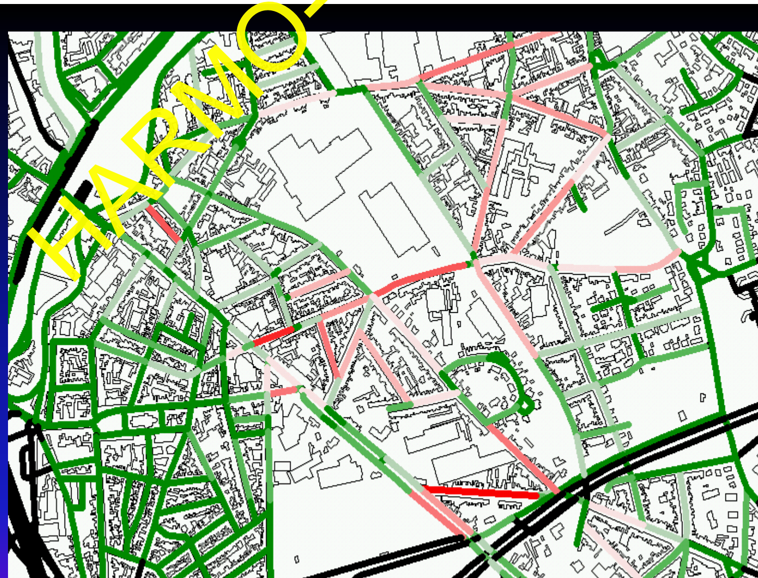
- Computational time required to calculate a scenario is limited and in the order of a few minutes: Gaussian approach is very fast!

Population densities per street and age group





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.

Acknowledgements

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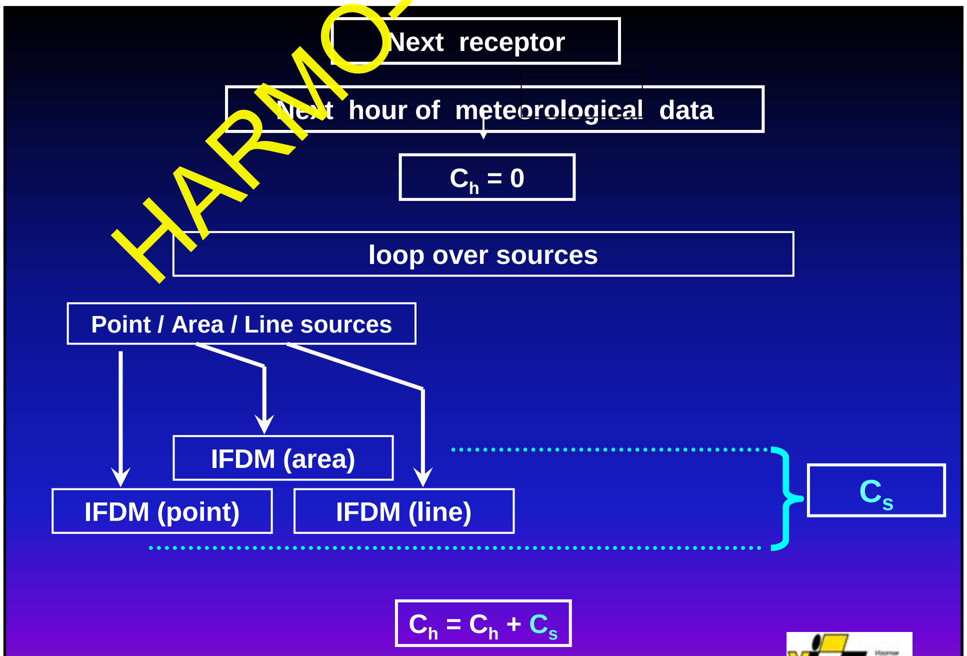


Next receptor

Next hour of meteorological data

$C_h = 0$

loop over sources

Point / Area / Line sources

IFDM (area)

IFDM (point)

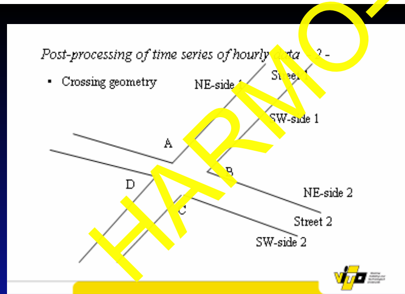
IFDM (line)

Street canyon geometry & emission

OSPM

C_s

$C_h = C_h + C_s$



Recep-Tor	street 1 NE	street 1 SW	street 2 NE	street 2 SW
A	←		←	
B		←	←	
C		←		←
D	←			←