A modelling approach for estimating background pollutant concentrations in urban areas

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Outline

- Background
- Modelling concept
- Urban increment model
- Results – Urban background concentrations for Germany
- Comparison against observations
- Summary and outlook

Background

- Urban population: 75% of the European population and by 2020 it will be for some countries even 90%[1].

- For several pollutants, higher concentrations levels are commonly found within urban areas.

- The number of people affected by elevated pollutant concentrations is notably higher in urban areas than in rural environments.

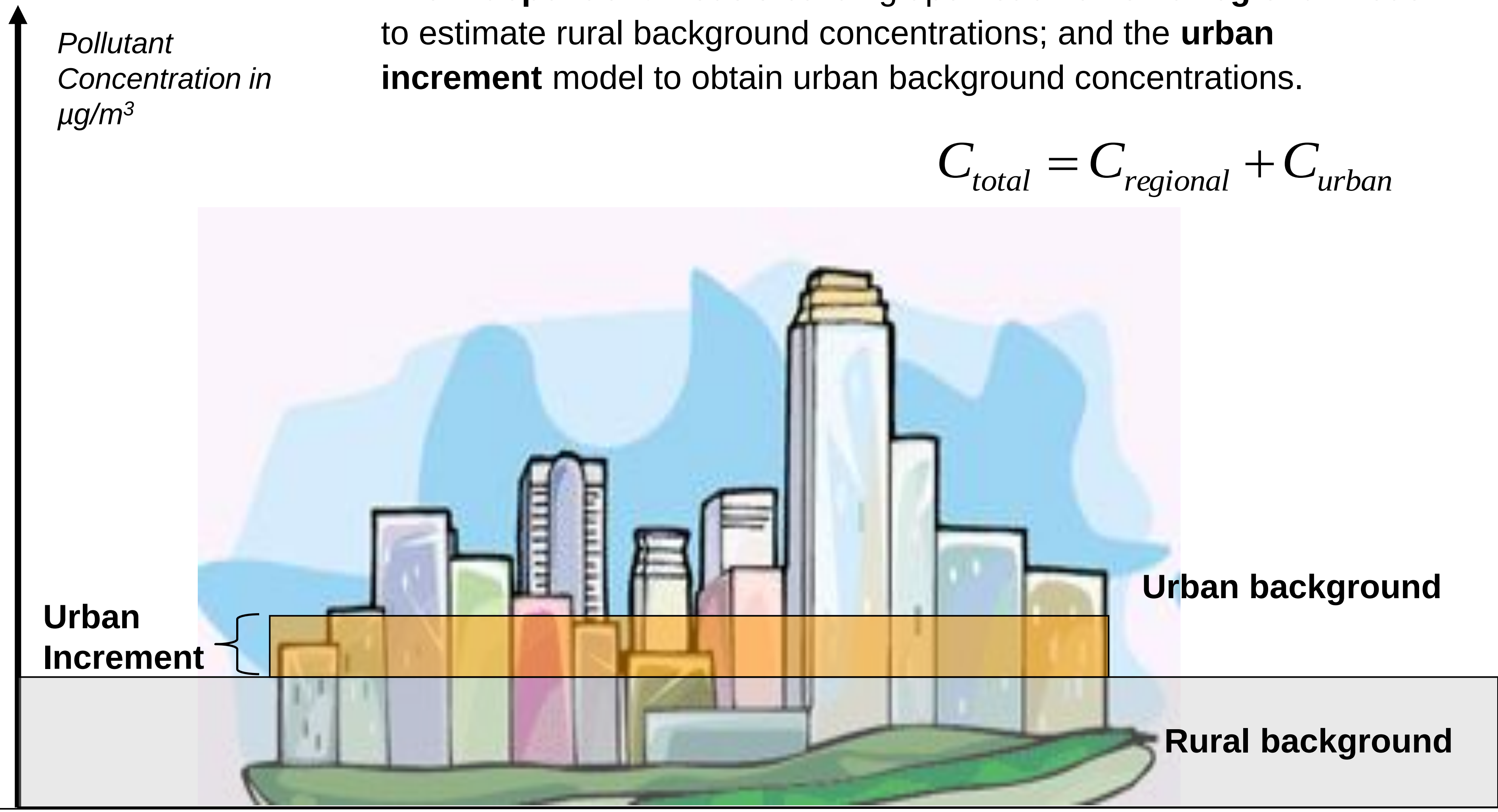
- Due to its relevance, the urban increment (i.e., the difference between regional and urban background pollutant concentrations) should be included in the analysis.

[1] Urban Sprawl in Europe. European Environment Agency, Report 2006-4

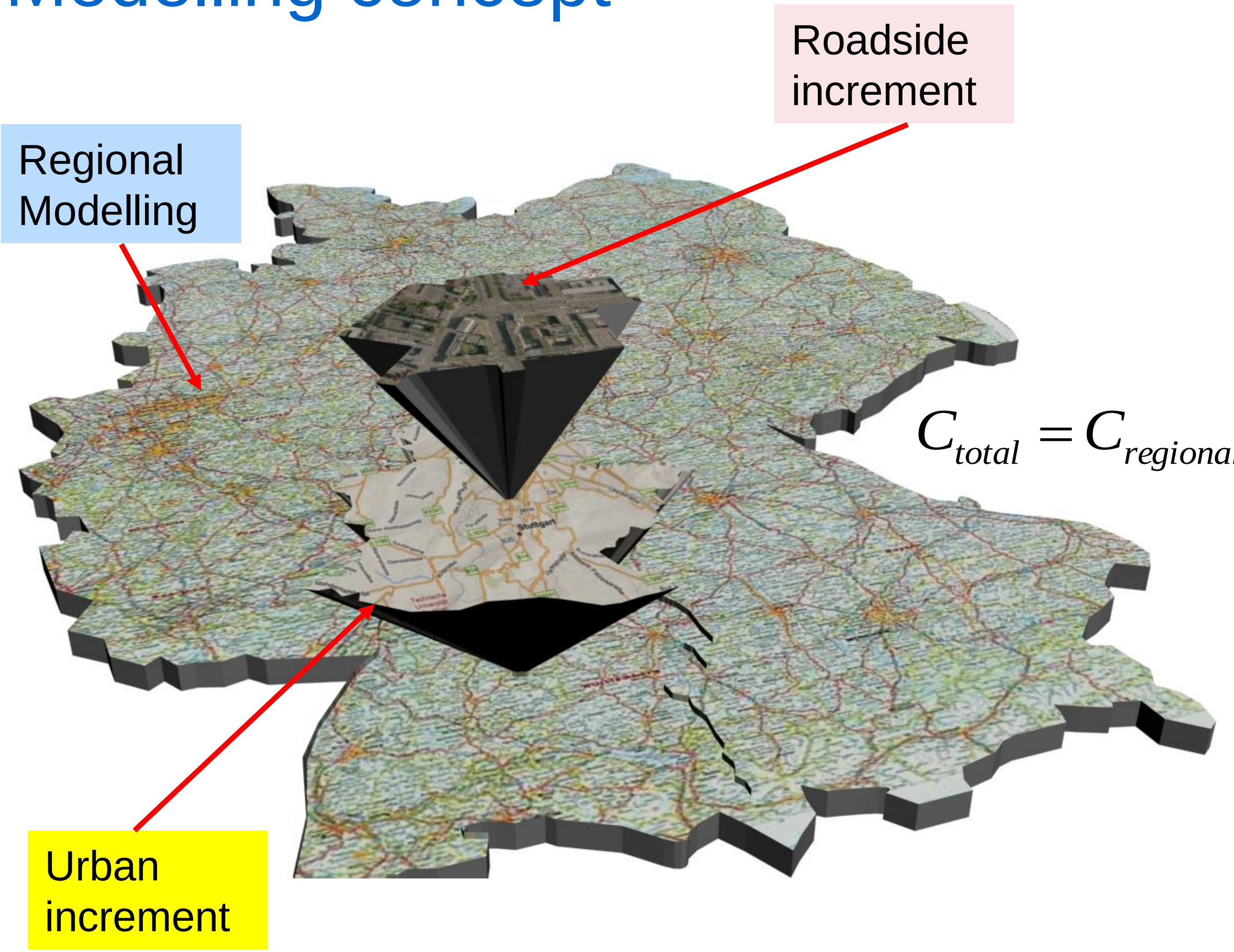
Modelling concept

Two **independent** models building upon each other: a **regional** model to estimate rural background concentrations; and the **urban increment** model to obtain urban background concentrations.

$$C_{total} = C_{regional} + C_{urban}$$



Modelling concept



$$C_{total} = C_{regional} + C_{urban} + C_{roadside}$$

Urban increment model

Based on past work carried out by e.g. by the CityDelta project, the urban increment model takes into account the following variables:

a) Measured urban increment: obtained using observational data from paired rural and urban background measuring stations

b) Urban area definition: the urban morphological zones proposed by Milego (2007) were used for defining the urban areas.

c) Urban emissions (114 German cities): Spatial resolved emission data sets were used.

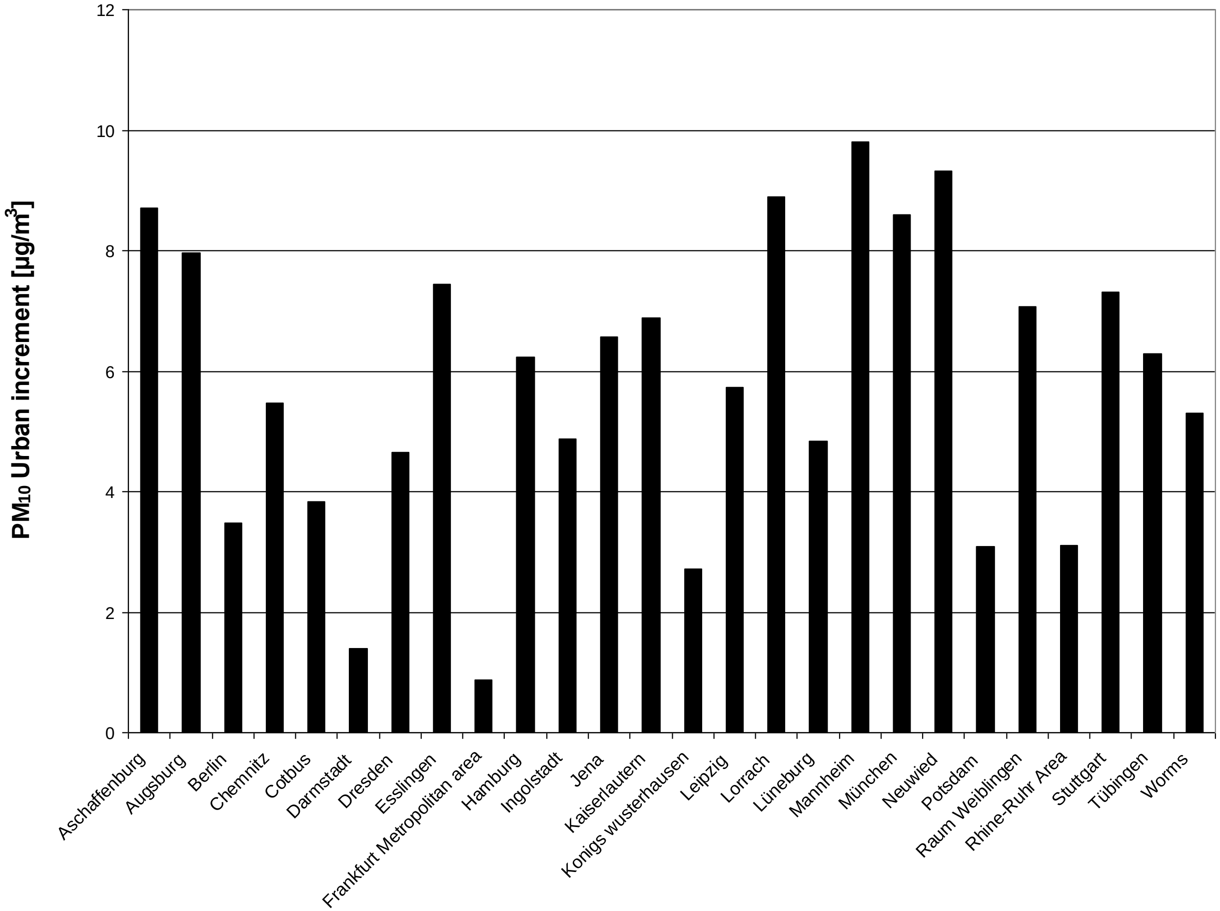
d) Wind speed: average 10-metres-over-the-surface wind speed was estimated for each urban area using a four-year dataset (1997, 2000, 2001 and 2003).

Note

The urban increment for $PM_{2.5}$ is estimated using a ratio $PM_{2.5}/PM_{10}$ of 0.75

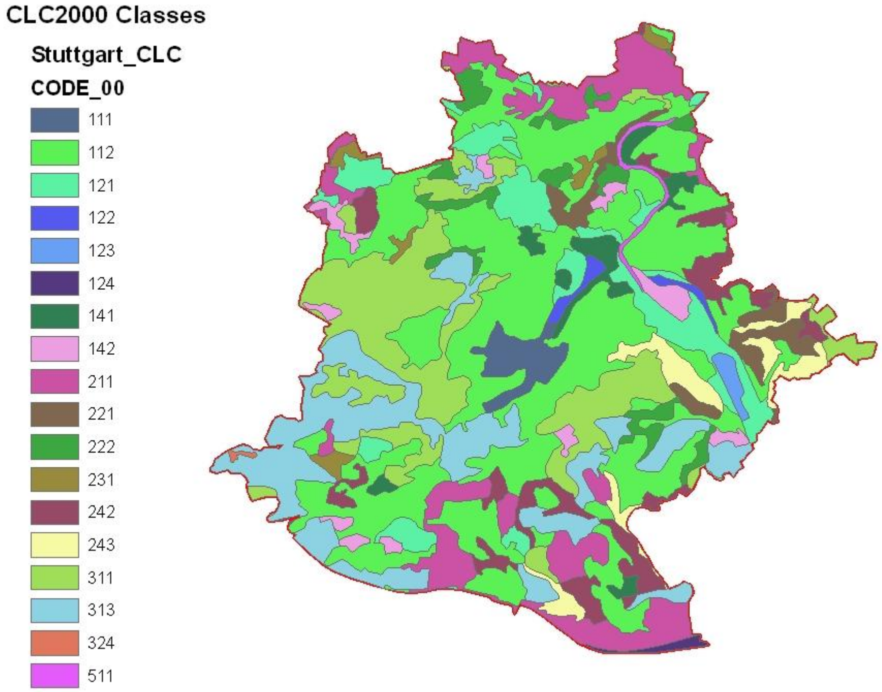
The urban increment for NO_2 is derived from modelled NO_X values on base of (Romberg et al. 1996; Bächlin et al. 2006)

A. Measured urban increment

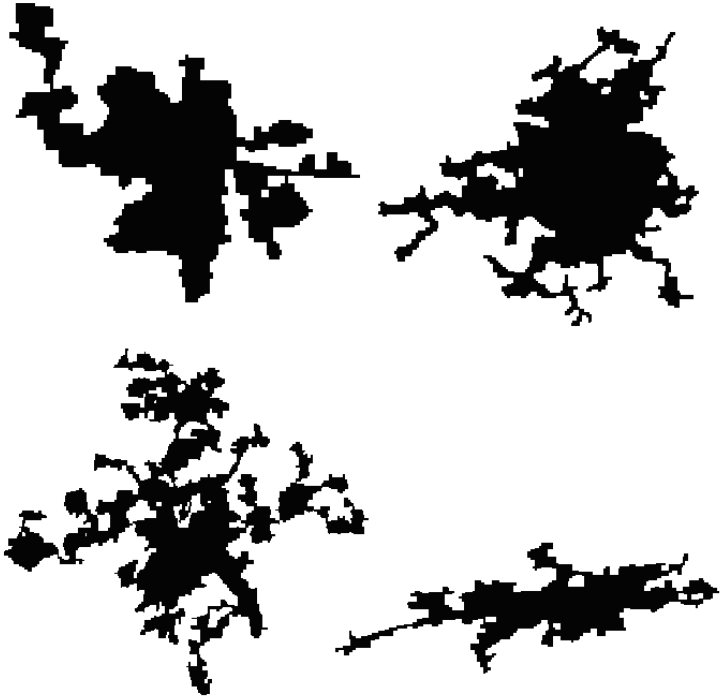


PM_{10} urban increment for several German cities estimated using observational data for urban and rural background paired stations

B. Urban area definition



Land use in the German district of Stuttgart according to CLC2000



Urban contours of Aachen, Chemnitz, Stuttgart and Kaiserslautern (from top left to right, without scale) determined following Milego (2007).

Urban increment model

Using the parameters described before, a multiple regression analysis was performed and the resulting formulation:

$$C_{i\ urban} = \varpi_i + \phi_i \frac{E_{iUE}}{A_{UE} \cdot u_{avg}} + \gamma\ C_{i\ rural}$$

where

C_i urban = Urban increment of pollutant i.

E_{iUE} = Total emission of pollutant i within the urban entity in tons.

A_{UE} = Urban entity area in km^2.

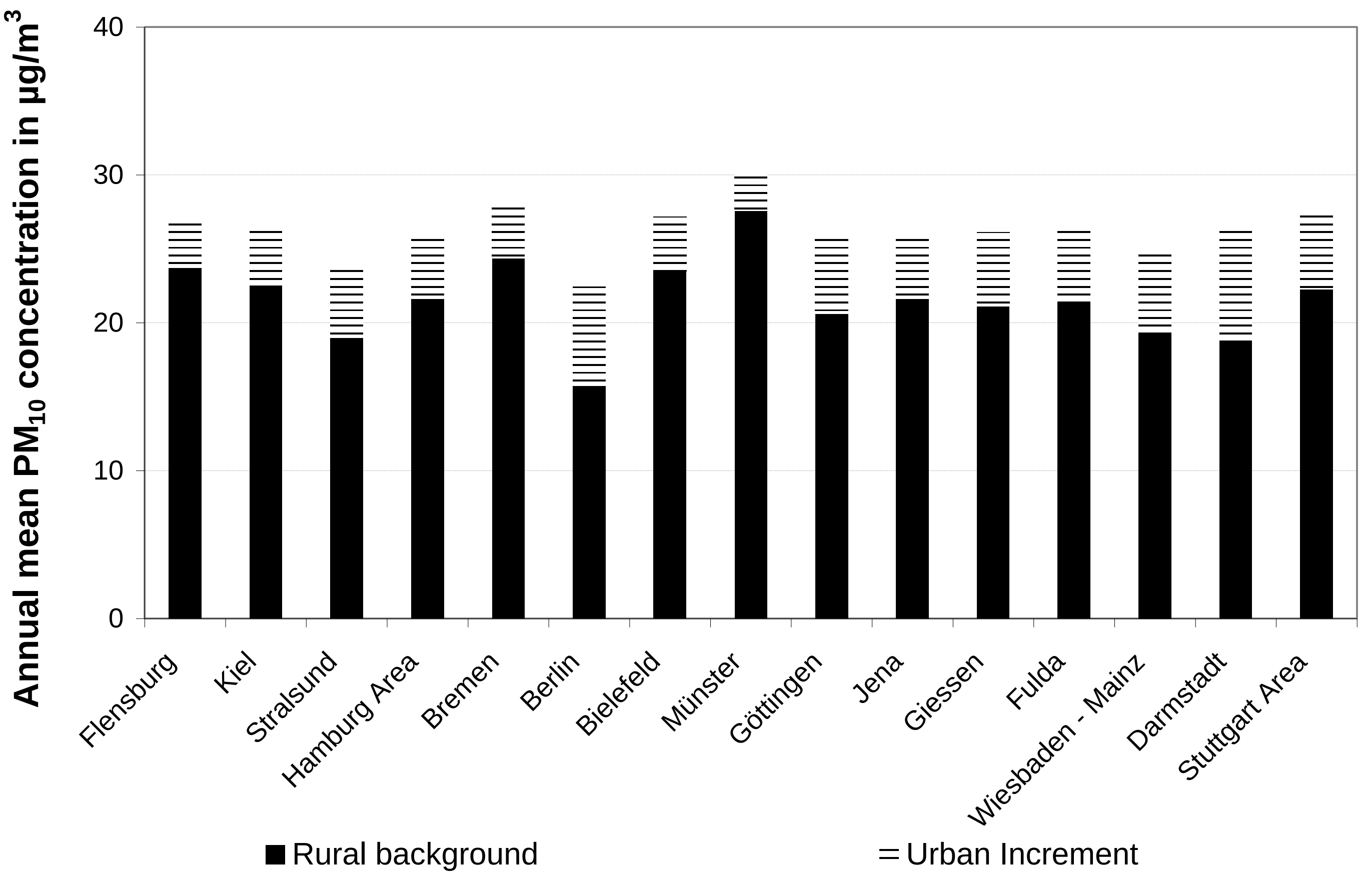
u_{avg} = Urban entity average wind speed in m/s.

$C_{i\ rural}$ = Rural background concentration of pollutant i in $\mu g/m^3$

ω_i, φ_i, and γ_i = Multiple-regression parameters for pollutant i.

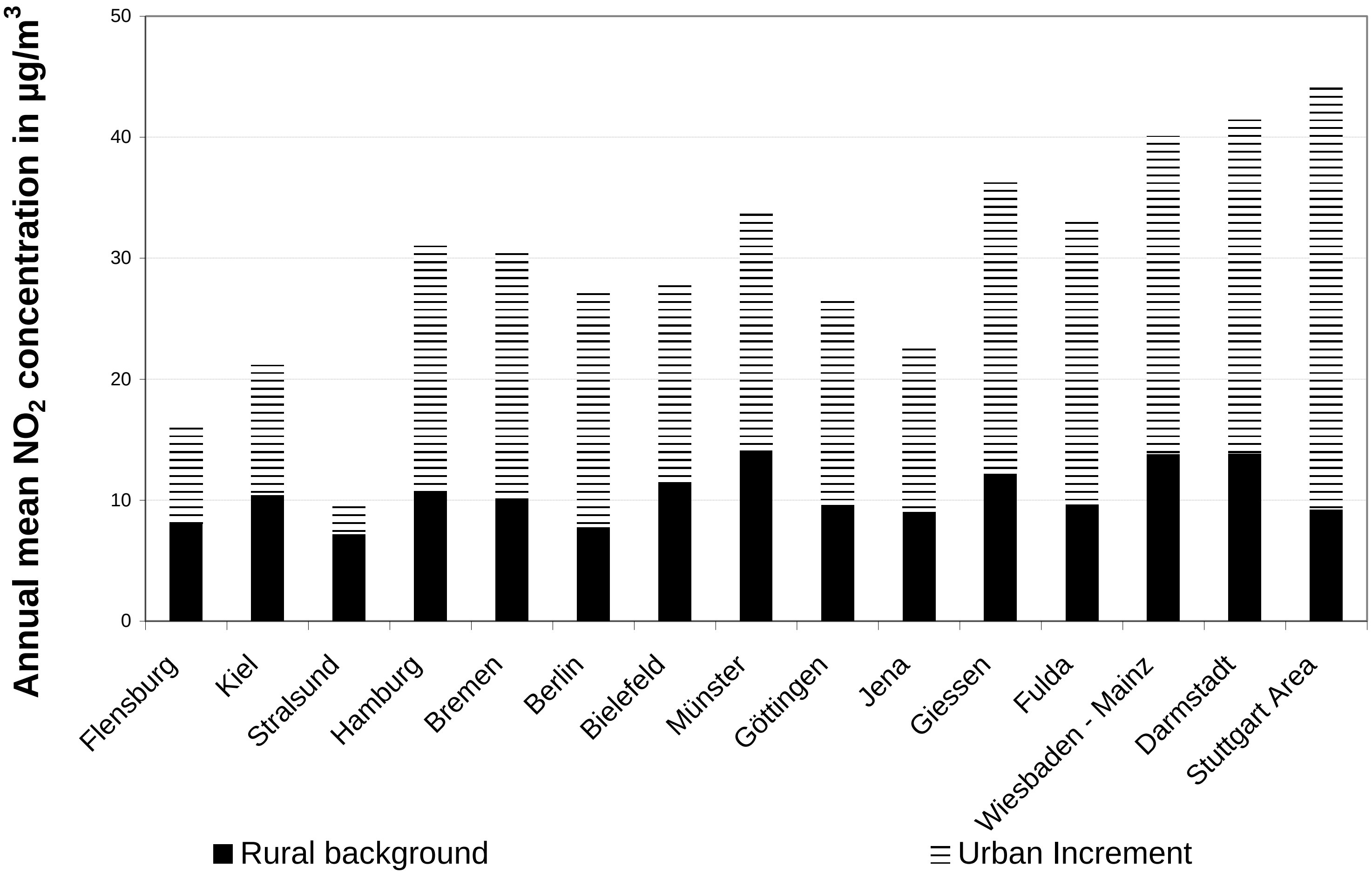
Double-counting is avoided adjusting the regional modelling results proportionally to the urban emissions allocated within the corresponding grid cell of the regional model

Urban increment – Modelling Results



Annual mean PM_{10} concentrations in fifteen large German urban entities

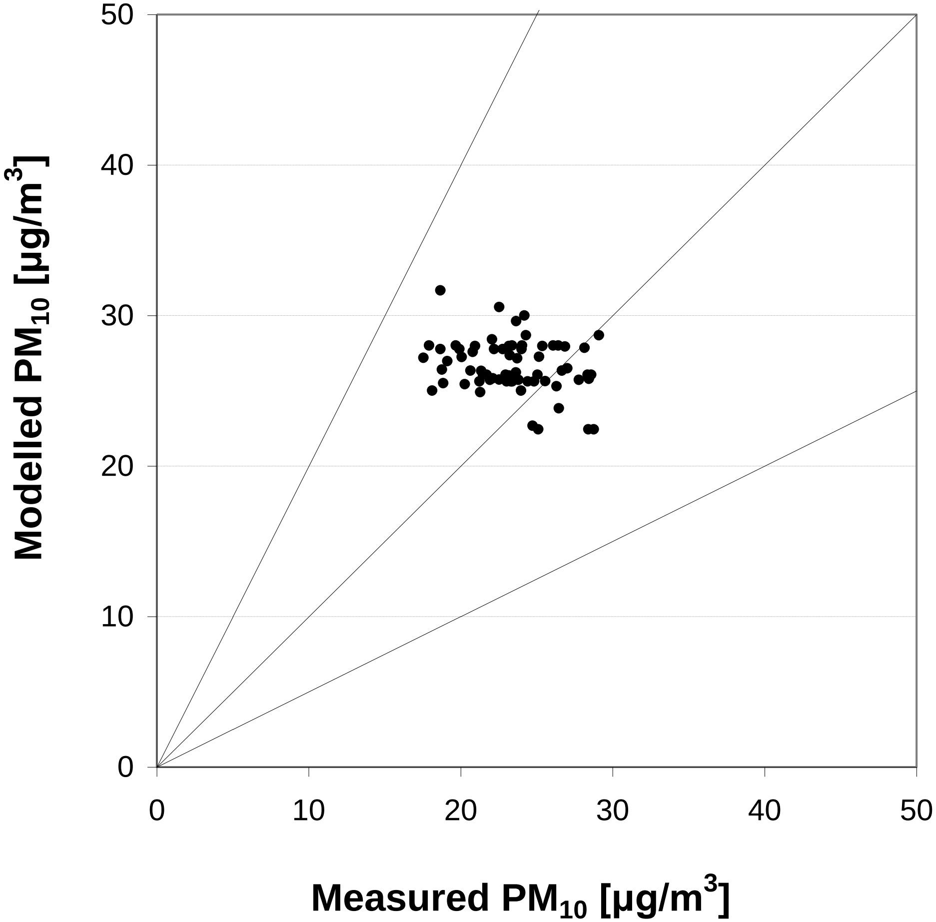
Urban increment – Modelling Results

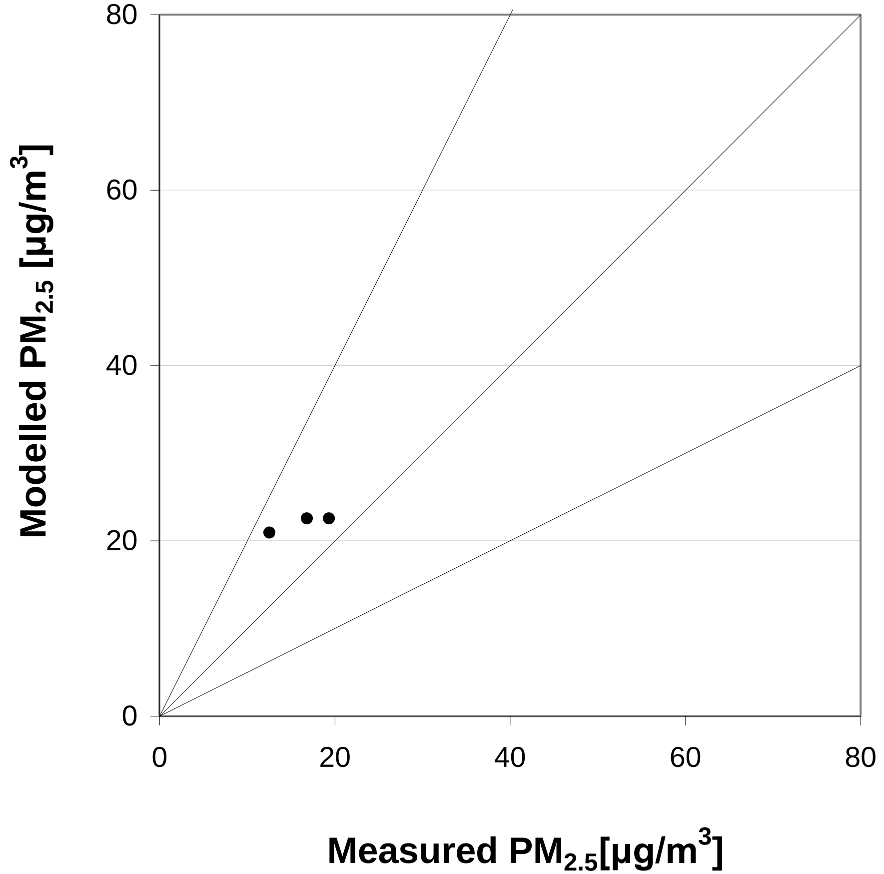


Annual mean NO_2 concentrations in fifteen large German urban entities

Model evaluation

Comparison of modelled values against measured concentrations at urban background stations





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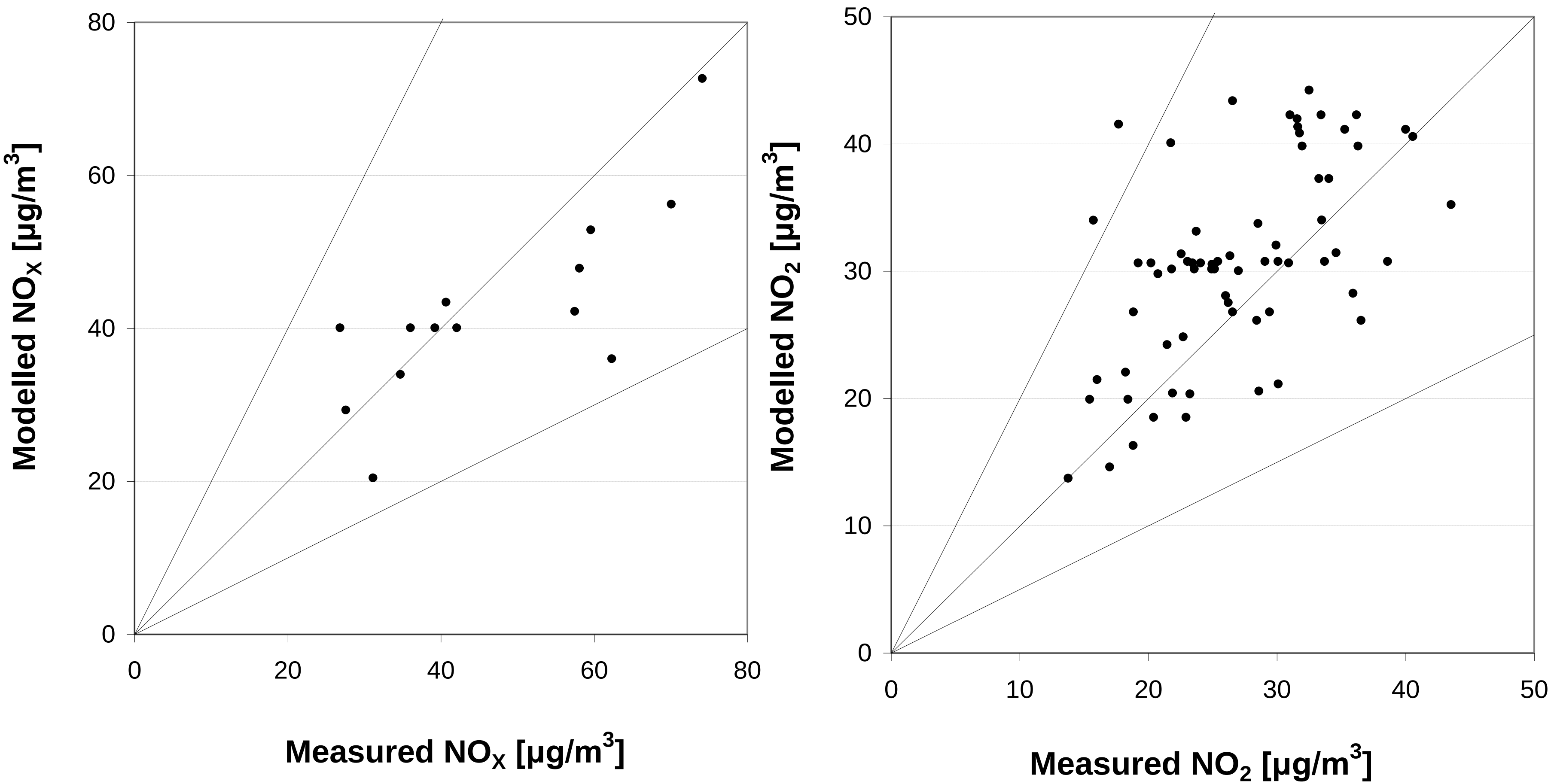


Summary

• A model to estimate the ‘urban increment’, which is defined as the distinguishable difference between the background concentration in a city and the levels measured outside the urban area, the urban increment, was developed.

• Combined with a regional atmospheric model the urban increment model can be used for estimating annual urban background concentrations of PM_{10}, $PM_{2.5}$, and NO_2.

• The model takes into account the actual urban sprawl and the urban increment was obtained from measured data and not modelled.

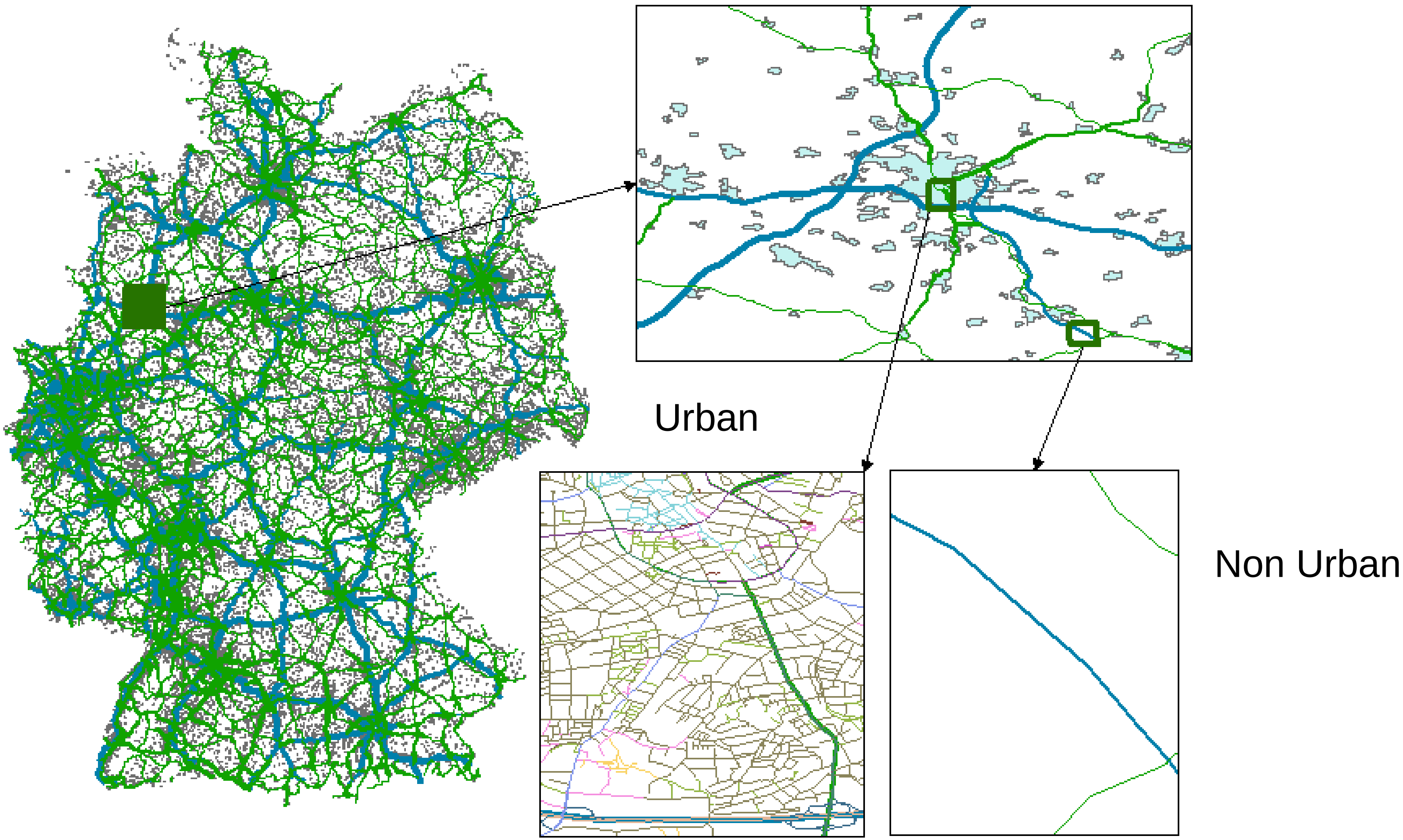
• A comparison against measured concentrations at urban background stations shows a good agreement.

• An extension of the model comprising the largest urban areas in Europe is currently under development.

•In addition have been also developed an approach for estimating roadside concentrations

Thank you for your attention

Roadside Increment



Roadside increment: urban

A Monte Carlo simulation with a parameterised model as underlying basis was used for estimating the additional concentration found at kerbside.

The CAR International dispersion functions (den Boeft et al., 1996 and Teewisse, 2006) were used as the underlying deterministic model to build the stochastic simulation algorithm as follows:

$$C_{roadside} = AADT \cdot EF \cdot \theta \cdot W \cdot F$$

AADT: Average Annual Daily Traffic
EF: Emission factor
W and F: Wind-speed and tree factor
Θ: dilution factor

AADT is described by a log-normal distribution function. The dilution factor is a function of street width and building height. The former is assumed to be normally distributed and the latter uniformly distributed

Roadside Increment: non-urban

MLuS 2000 – Technical leaflet on air pollution along roads

$$K_i\,(s) = K_n * e_i * g(s) * f_u$$

Where:
K_i = concentration of pollutant i at a distance s [mg/m^3]
e_i = local street emission [mg/m · hr]
K_n = is the near-ground concentration related to the local street emission e_i
g(s) = dispersion function; It is estimated using:

$$g(s) = 1- 1.166 \ln (1+s)$$

Where s is the distance between road and observation point
fu = function to consider wind speed; It is evaluates as follows:

$$f_u = \frac{2.3}{u}$$

where u is the annual average wind speed in m/s measured at 10 metres over the surface.