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Karlsruhe und Dresden

Modelling Incremental Concentrations from Domestic Heating with the Regulatory Lagrangian Particle Model AUSTAL2000

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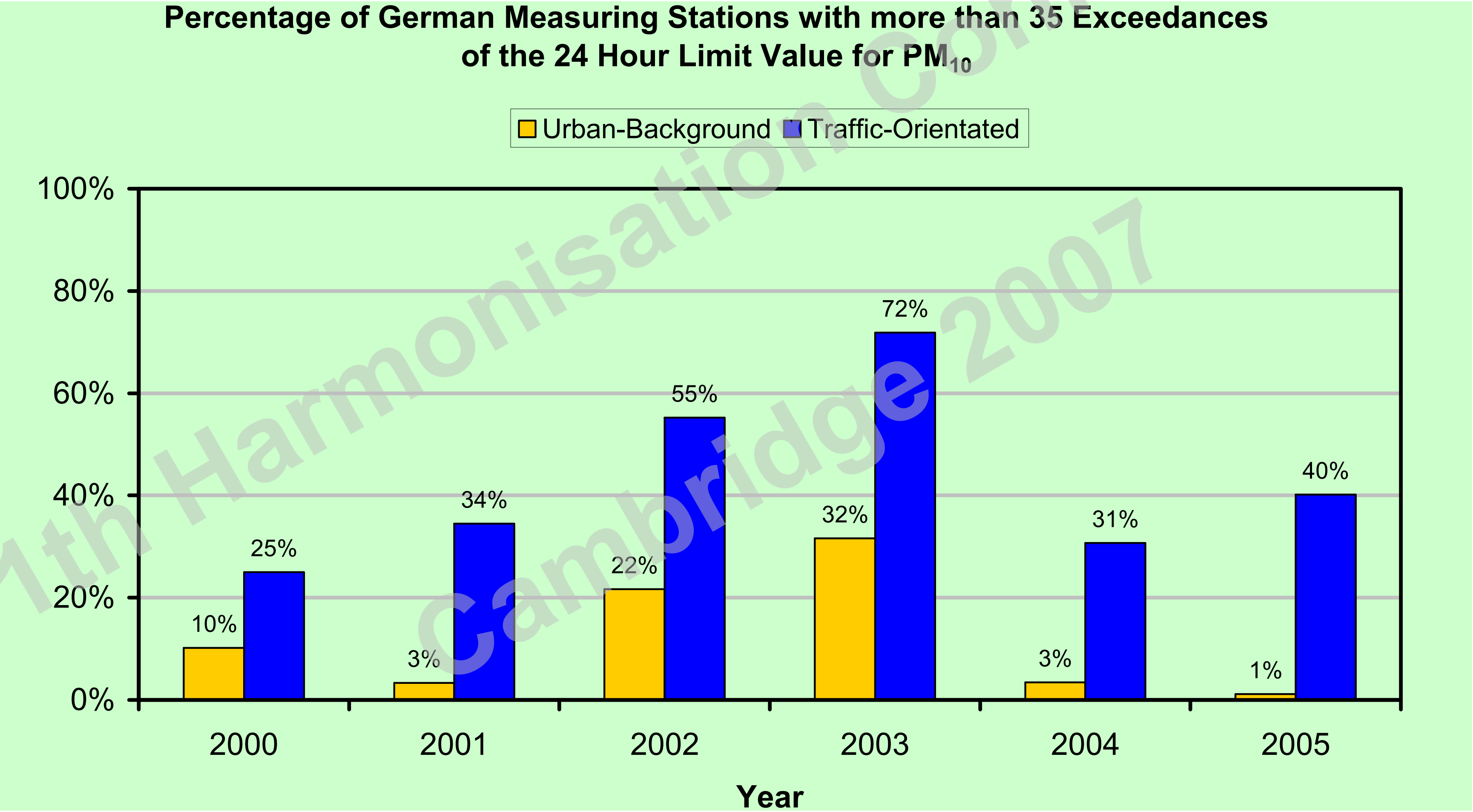
Introduction

Why modelling homes – aren't concentrations from residential combustion irrelevant?

High Ambient PM_{10} Concentrations



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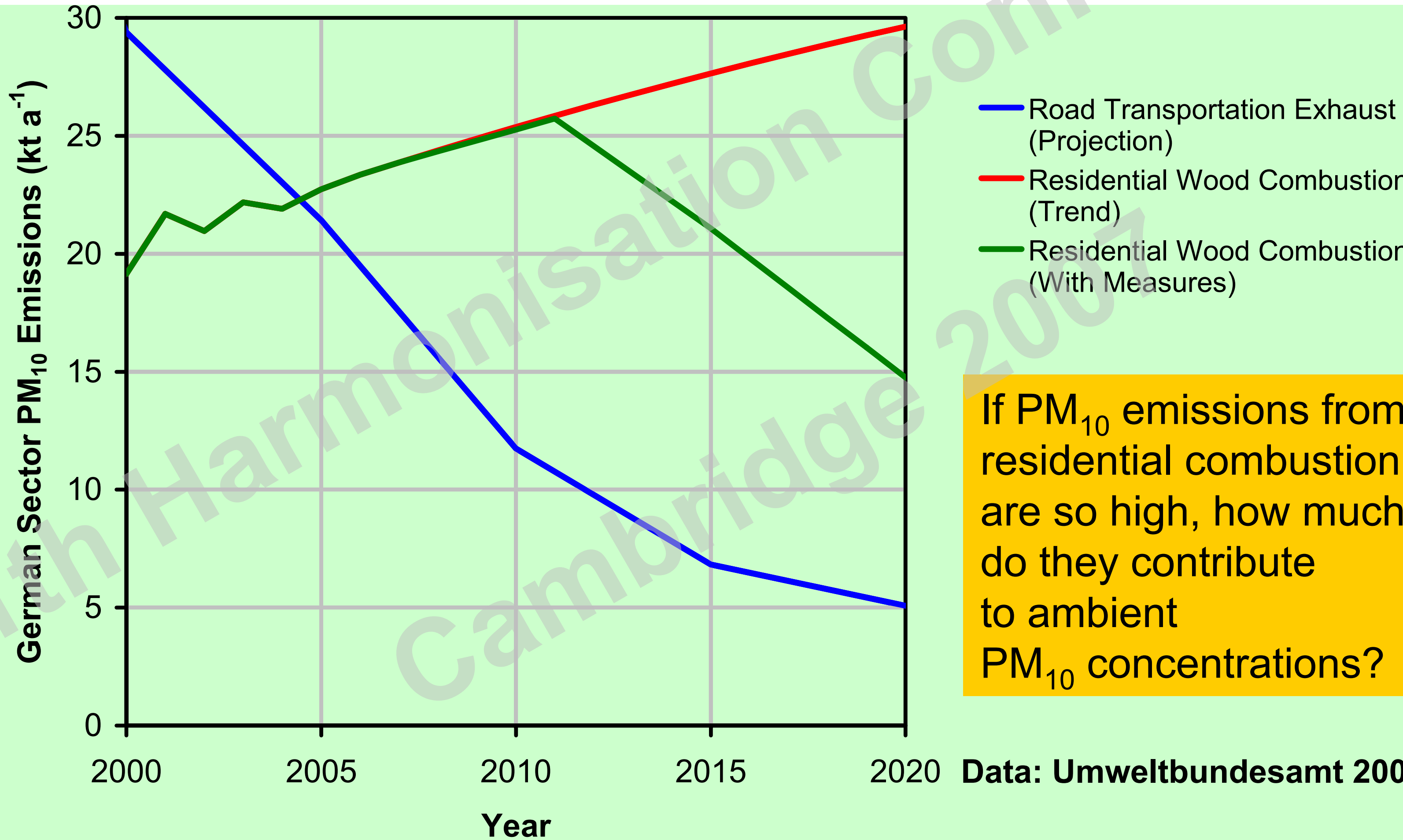
High PM_{10} Emissions



If PM_{10} emissions from residential combustion are so high, how much do they contribute to ambient PM_{10} concentrations?

Data: Umweltbundesamt 2007

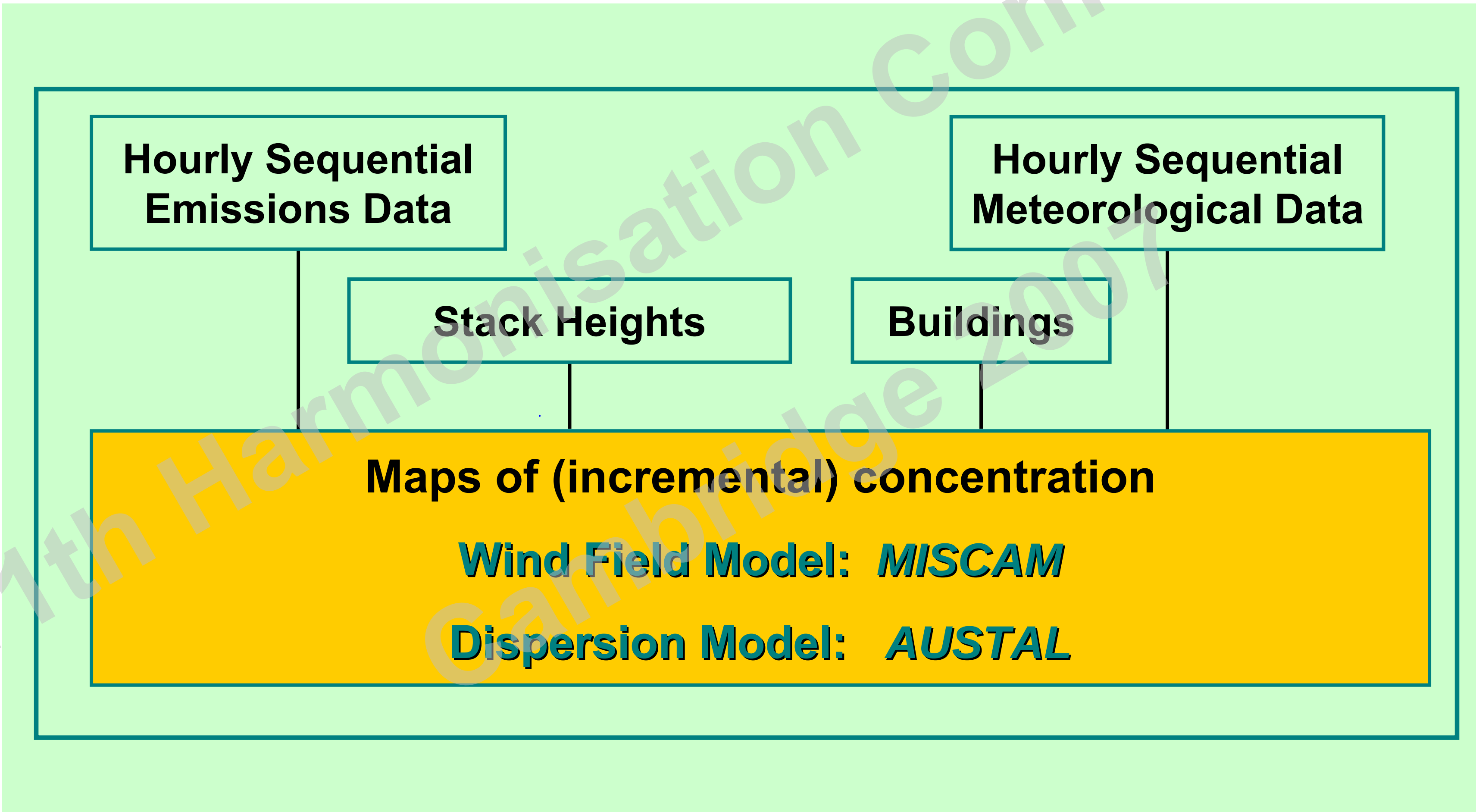
Method

Conceptual Framework

- Assess concentrations by means of regulatory model
- Residential area = "plant" = domain
- Hundreds of buildings
- Hundreds of individual sources (≈ 1 per building)
- Evaluate concentrations between buildings
- Explore solution space by means of scenario runs

  (Type of stove/boiler, meteorology, building density, …)

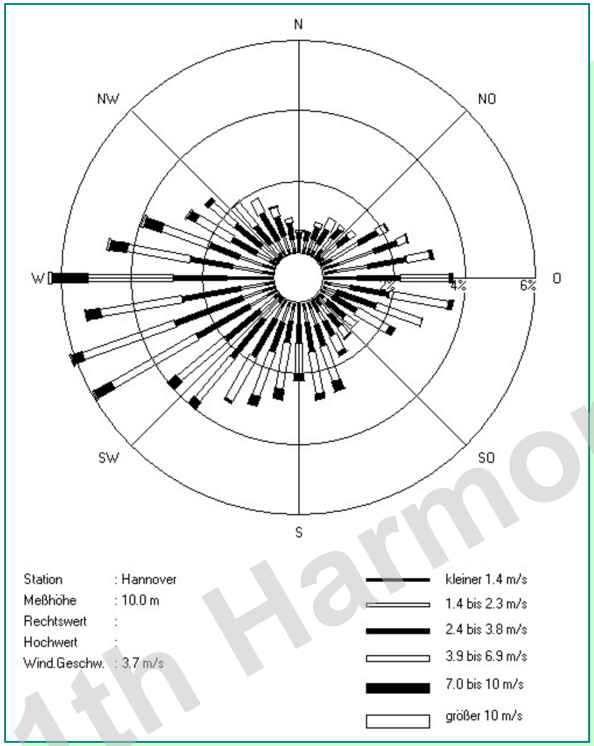
Flow Chart

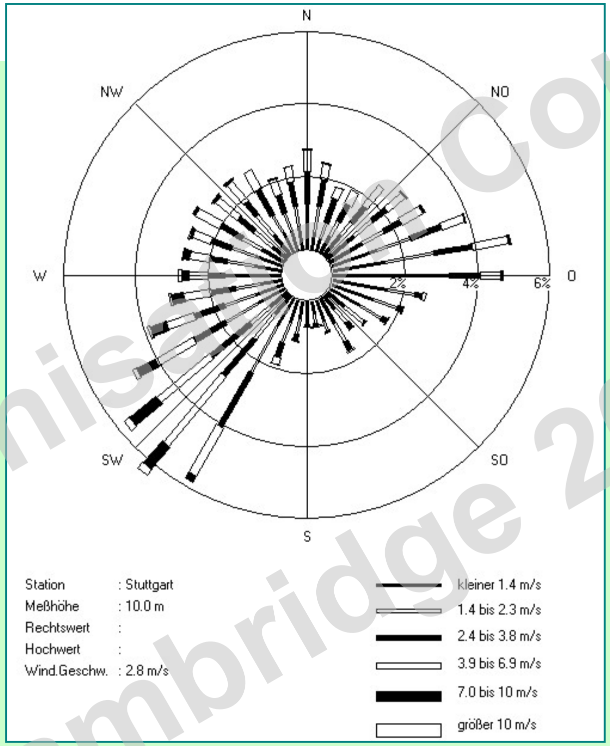

Hourly Sequential
Emissions Data
Hourly Sequential
Meteorological Data
Stack Heights
Buildings
Maps of (incremental) concentration
Wind Field Model: *MISCAM*
Dispersion Model: *AUSTAL*

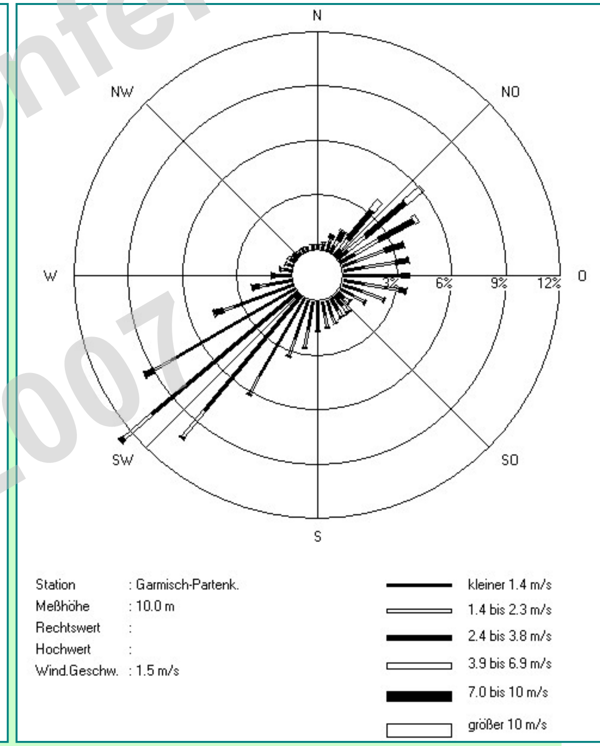
Modelling Emission Data

- Most important, but beyond the scope of this talk
- Provided by Institute of Process Engineering and Power Plant Technology (IVD), University of Stuttgart
- 8760 hourly values – individually for each building
- Taking into account
  - Type of fuel
  - Type and technical standard of stove or boiler
  - Stationary and non-stationary states of combustion
  - Area of building envelope
  - Energy performance standard of building
  - Ambient temperature: 8760 hourly sequential values, 15 German climate regions (courtesy of DWD 2006)

Meteorology – Wind Statistics







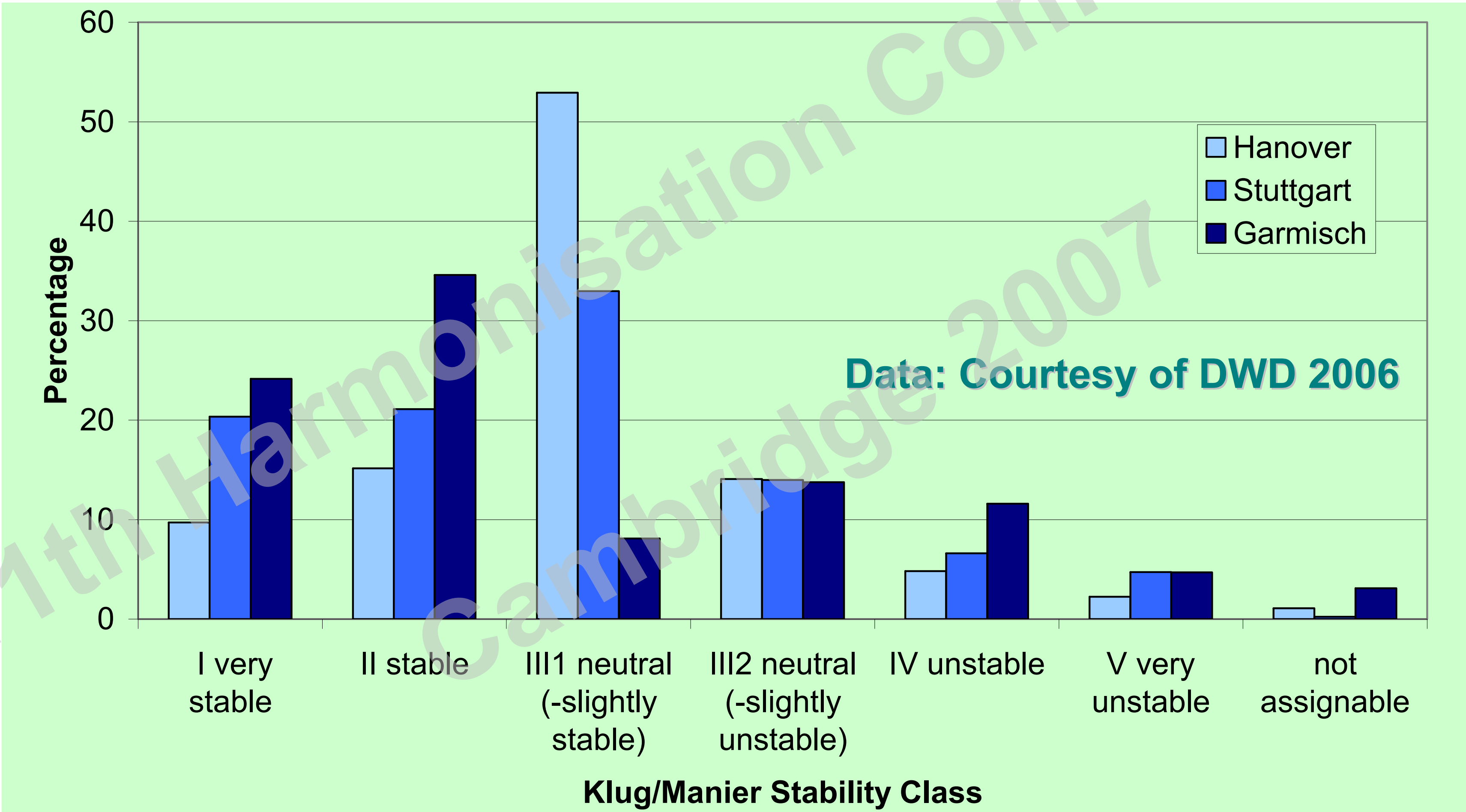
Hanover
$v_a = 3.7\ m\ s^{-1}$

Stuttgart
$v_a = 2.8\ m\ s^{-1}$

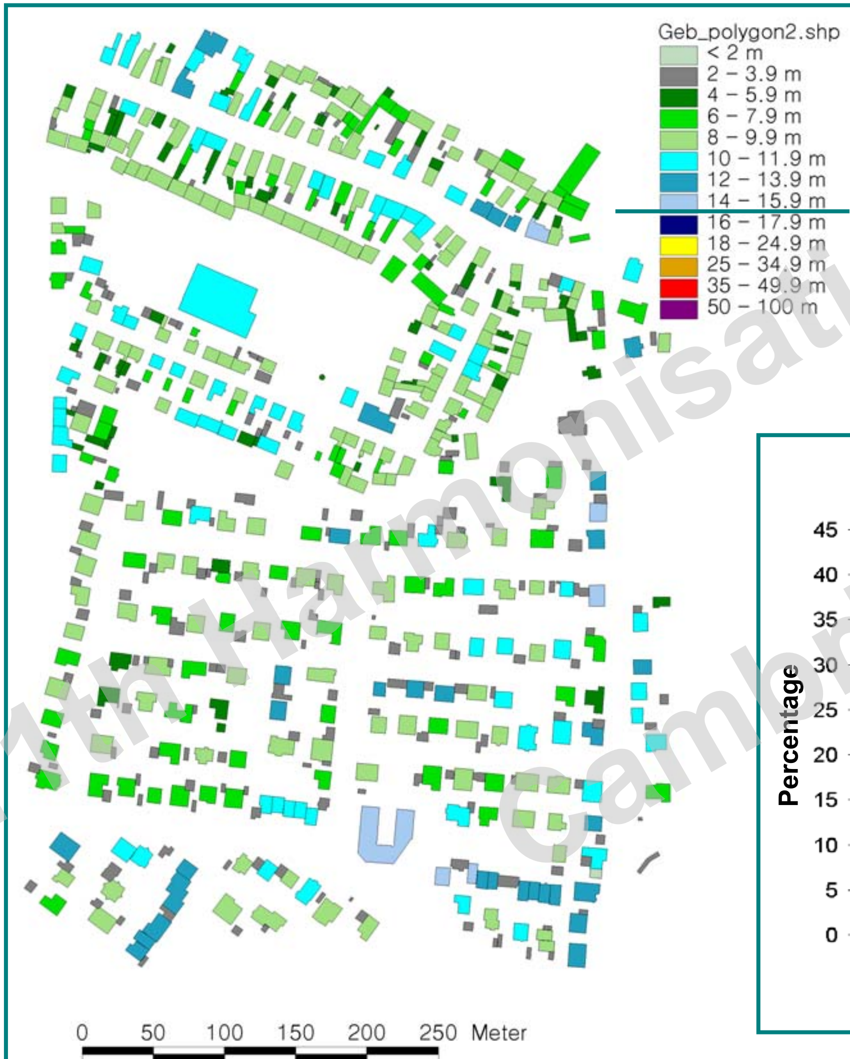
Garmisch-Partenkirchen
$v_a = 1.5\ m\ s^{-1}$

Data: Courtesy of DWD 2006

Meteorology – Stability Classes



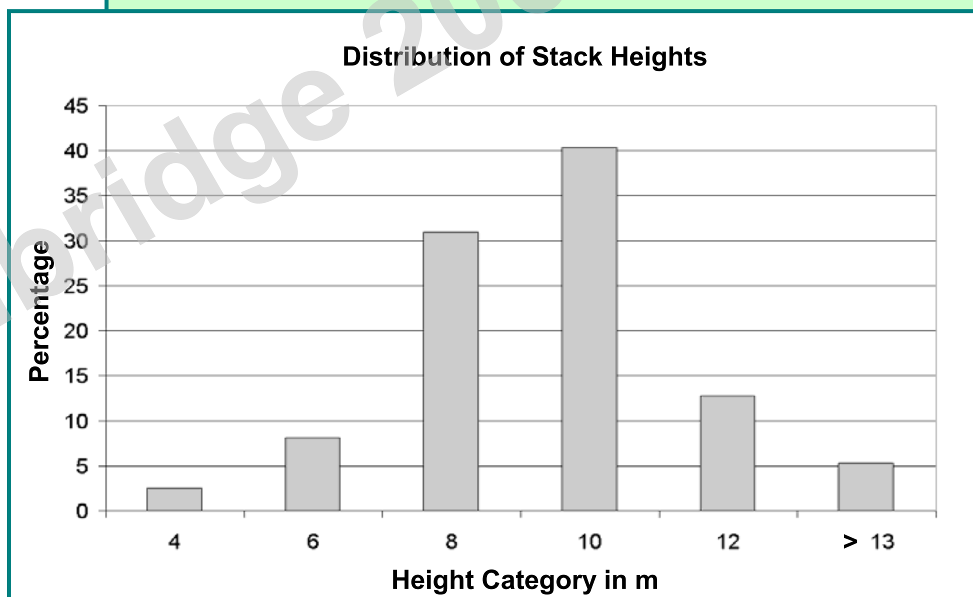
Model of a Rural Residential Area



Size: 800 m x 600 m

Built-Up Area: 18 %

Number of Sources: 320



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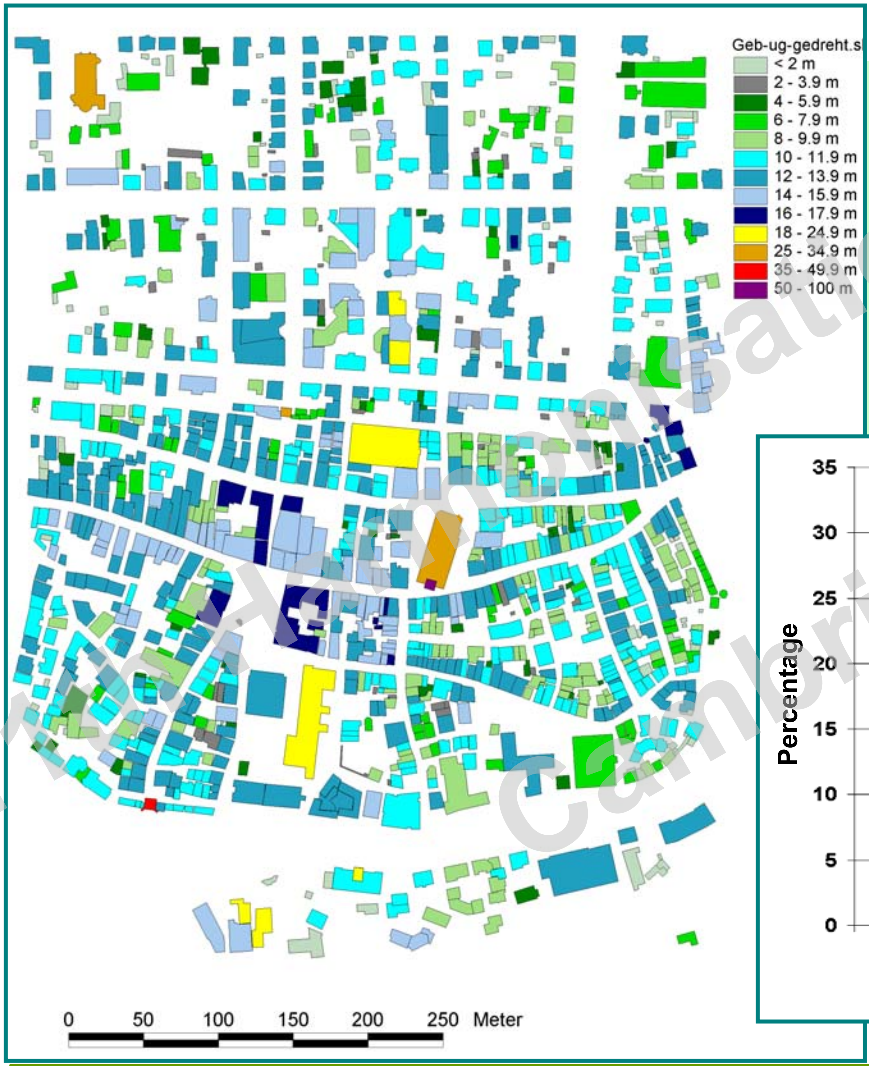
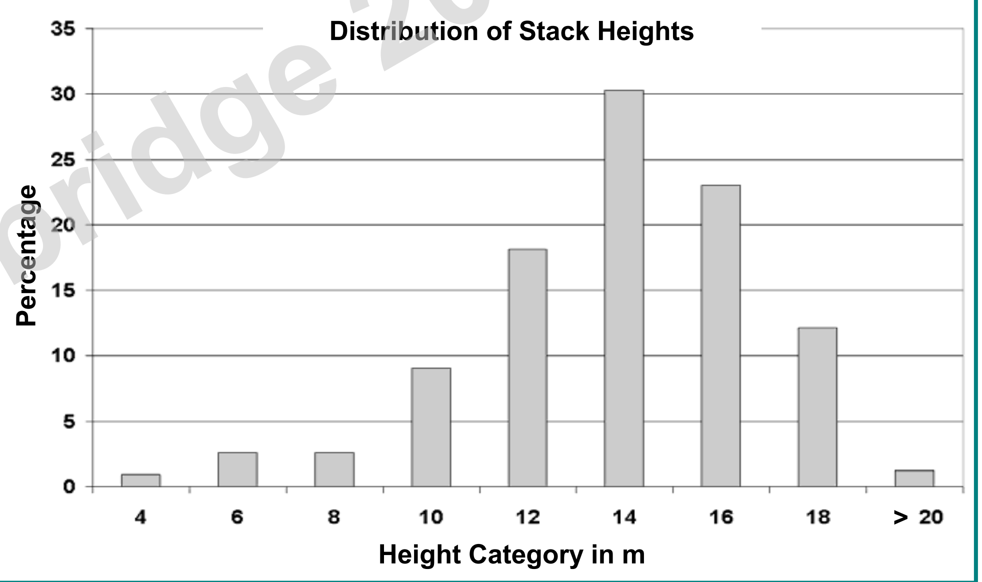
Model of an Urban Residential Area



Size: 800 m x 600 m

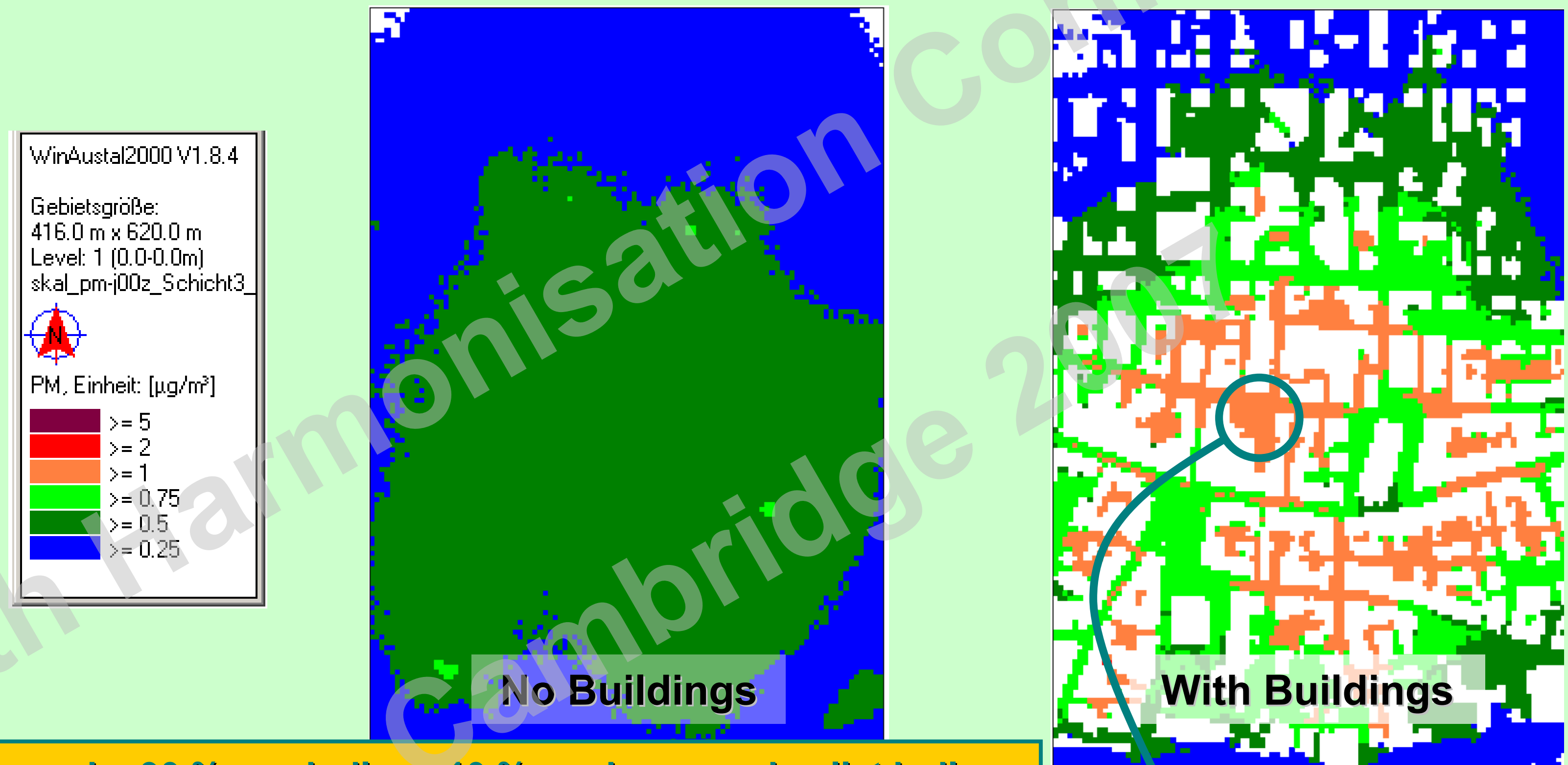
Built-Up Area: 34 %

Number of Sources: 651



Sensitivity Studies

Effect of Obstacle Flow



Energy mix: 90 % gas boilers, 10 % modern wood pellet boilers

	No Buildings	With Buildings
Mean Concentration	**0.6 µg m^{-3}**	**0.9 µg m^{-3}**
Local Maximum	**0.8 µg m^{-3}**	**1.5 µg m^{-3}**

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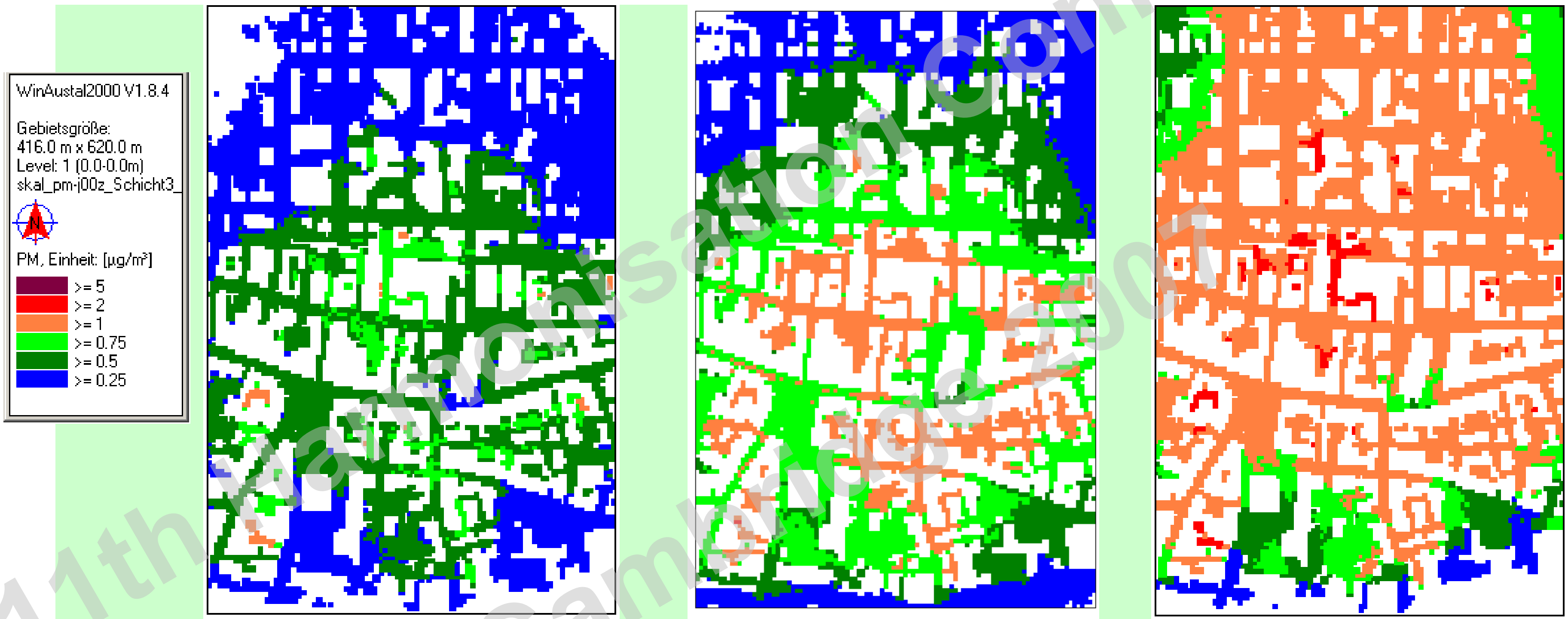
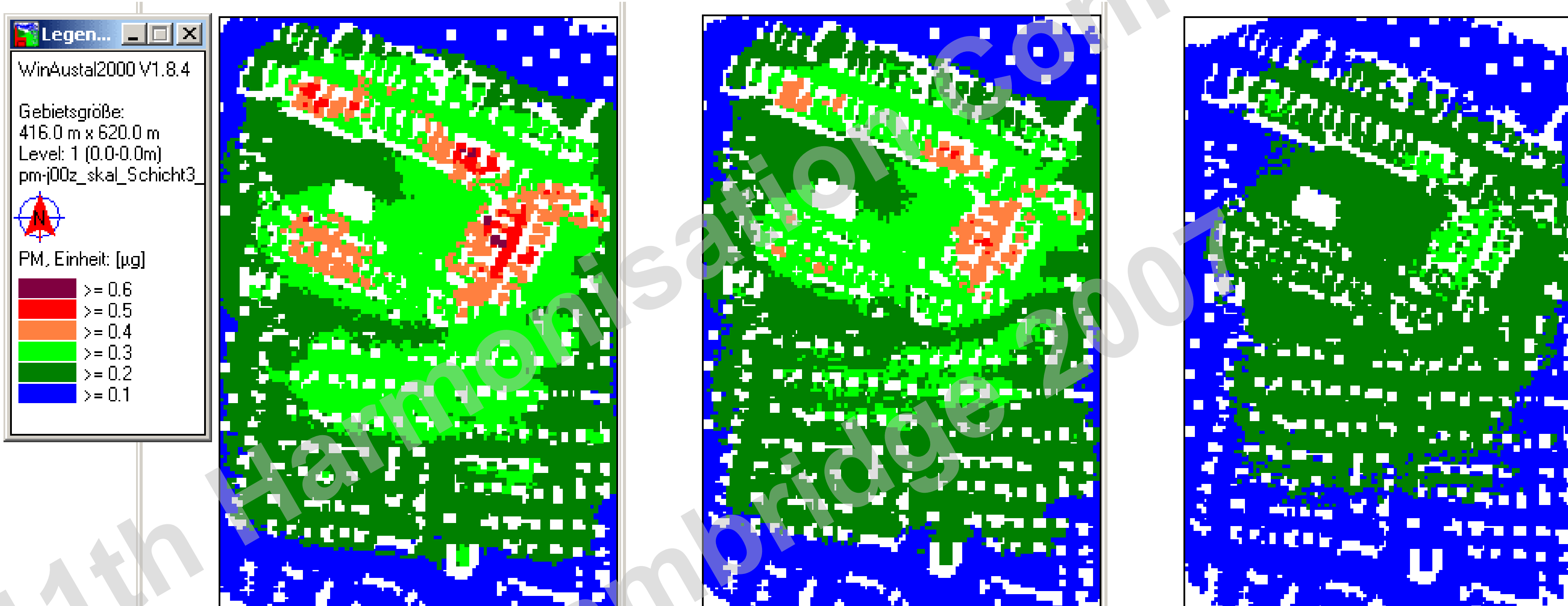
Effect of Meteorology – Wind



	Hanover $v_a = 3.7\ m\ s^{-1}$	Stuttgart $v_a = 2.8\ m\ s^{-1}$	Garmisch $v_a = 1.5\ m\ s^{-1}$
Area Mean	0.6 µg m^{-3}	0.9 µg m^{-3}	1.5 µg m^{-3}
Local Max	1.0 µg m^{-3}	1.5 µg m^{-3}	2.1 µg m^{-3}

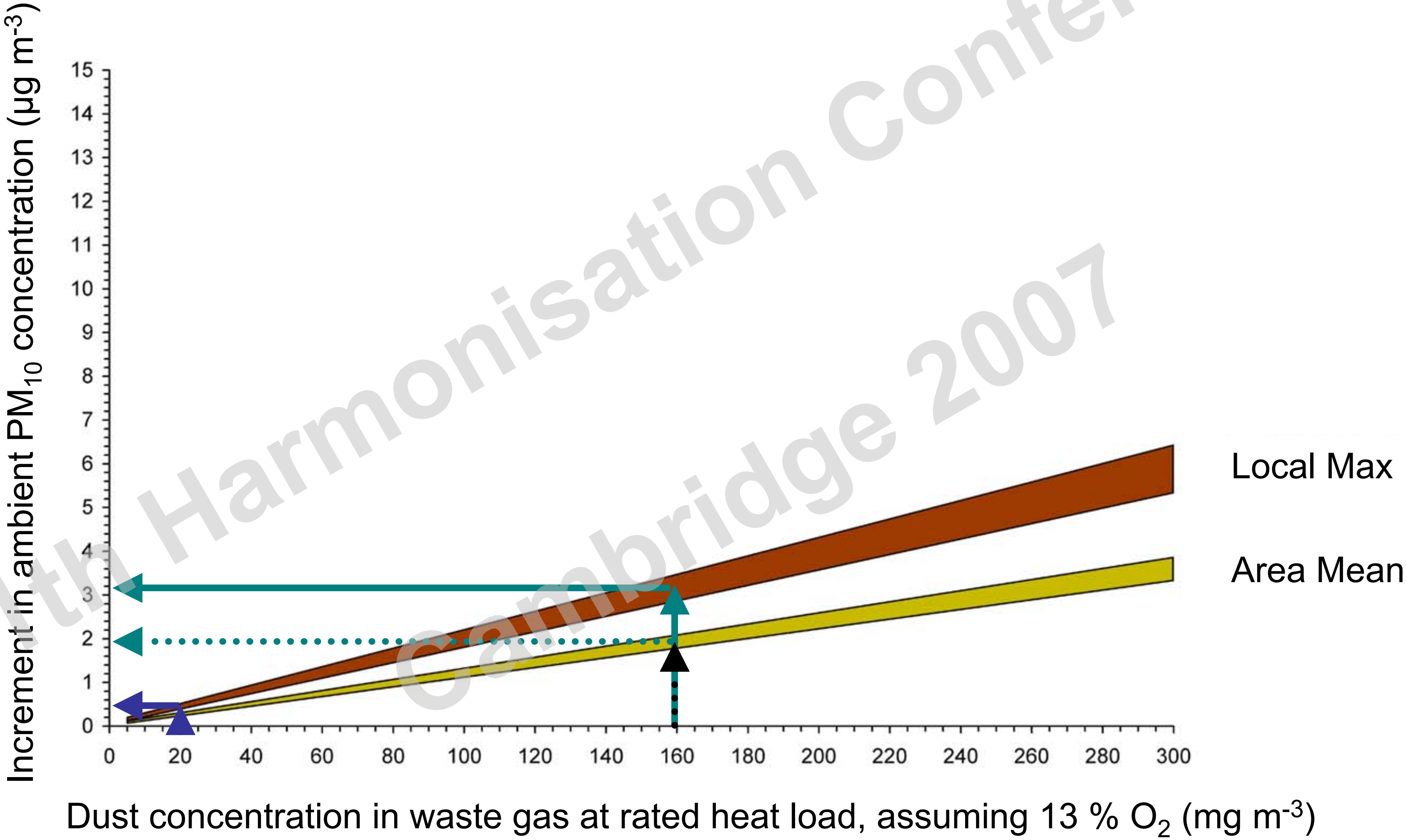
Effect of Chimney Height



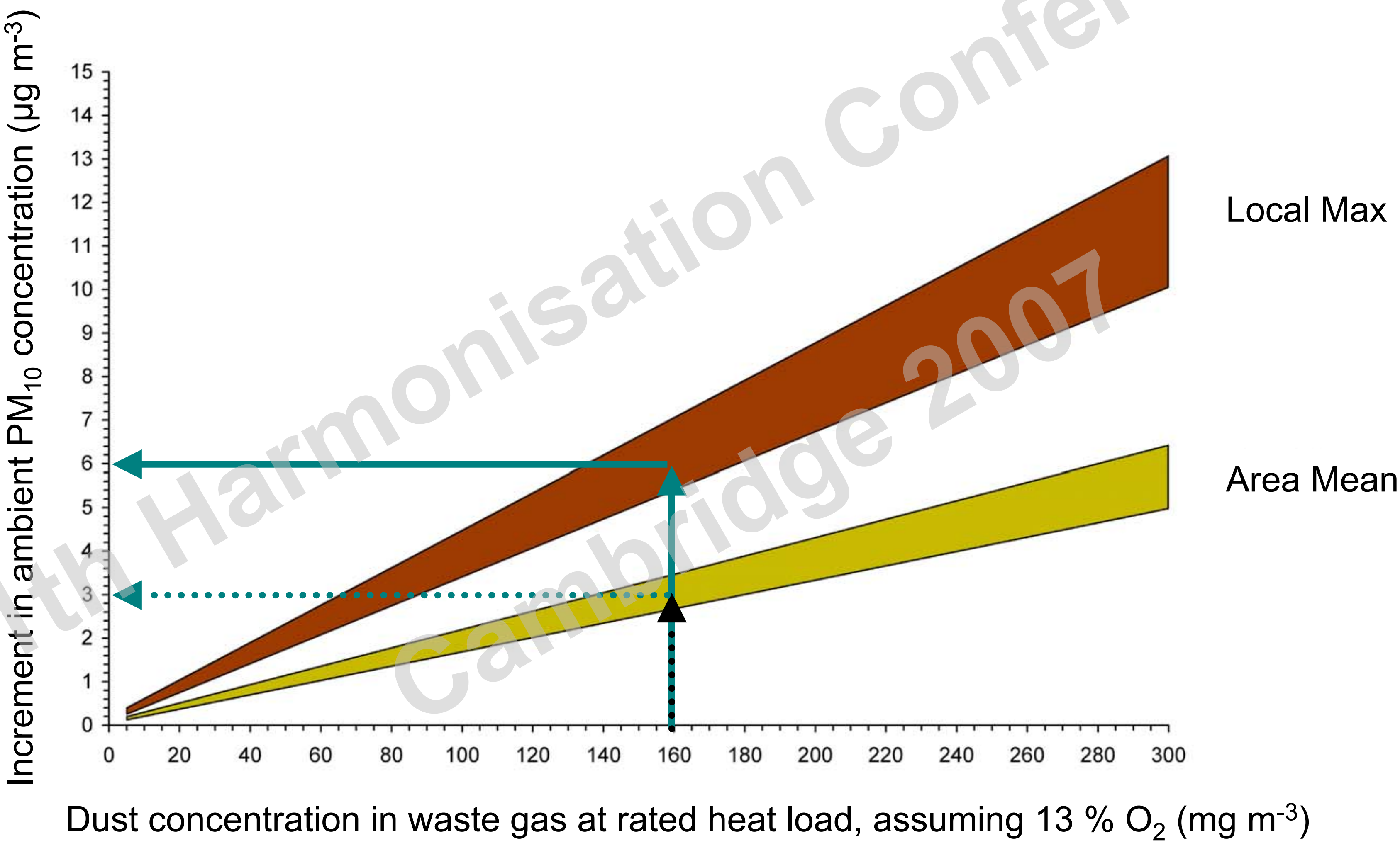
Stack Height	At Ridge	Ridge + 1 m	Ridge + 3 m
Area Mean	100%	92%	72%
Local Max	100%	84%	55%

Selected Results

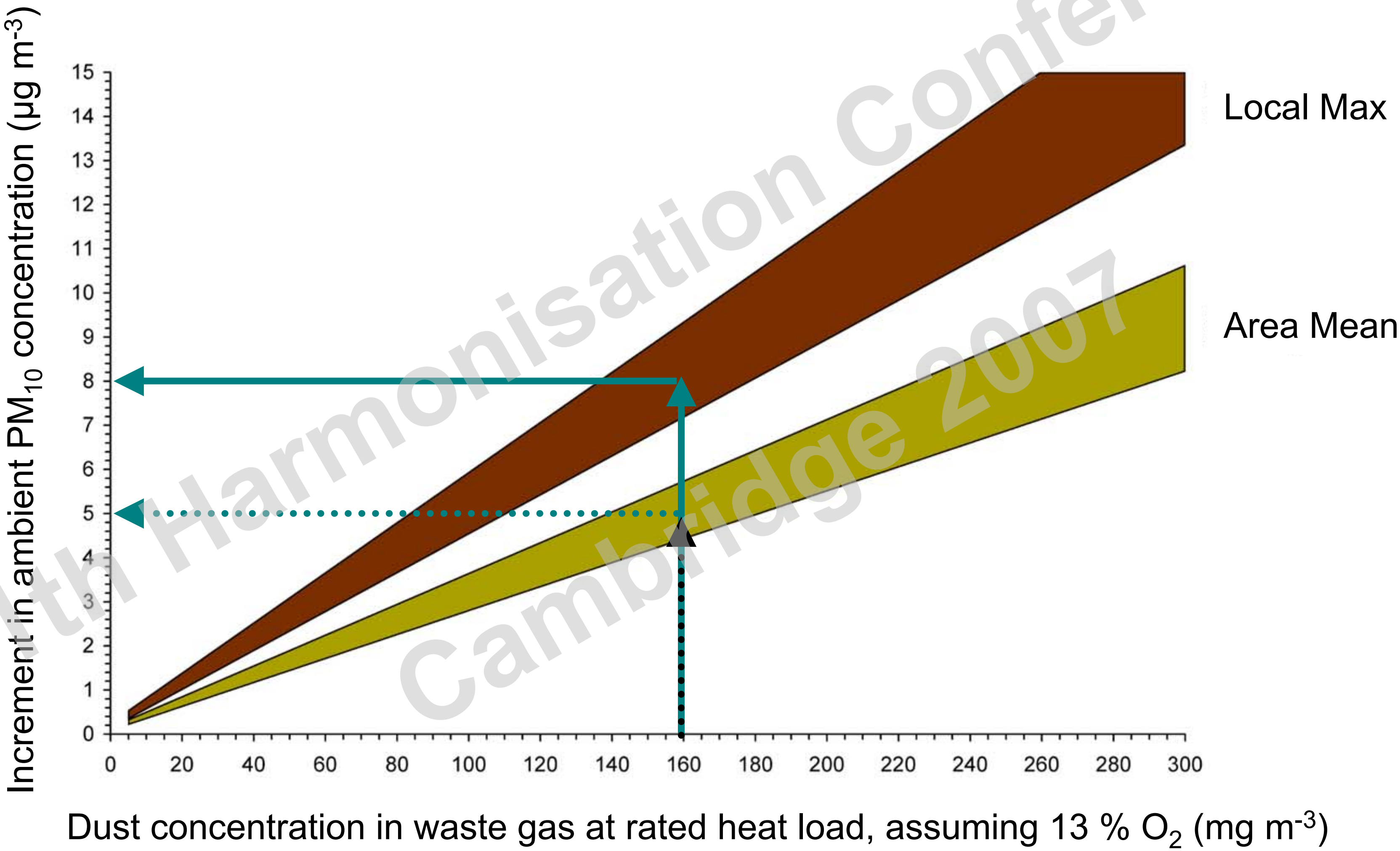
Rural Area, 10 % Wood Boilers



Rural Area, 10 % Wood Boilers, Cold + Low Wind



Urban Area, 10 % Wood Boilers



Conclusions

- Micro-scale approach crucial in residential area
- AUSTAL2000 applicable in the micro-scale
- Interfacing with Eulerian flow models hampered by different conventions for parameterization of turbulence
- Significant effects of wind speed and chimney height
- PM_{10} concentrations from residential wood combustion typically 1–10 µg m^{-3} in Germany

11th Harmonisation Conference

Cambridge 2007

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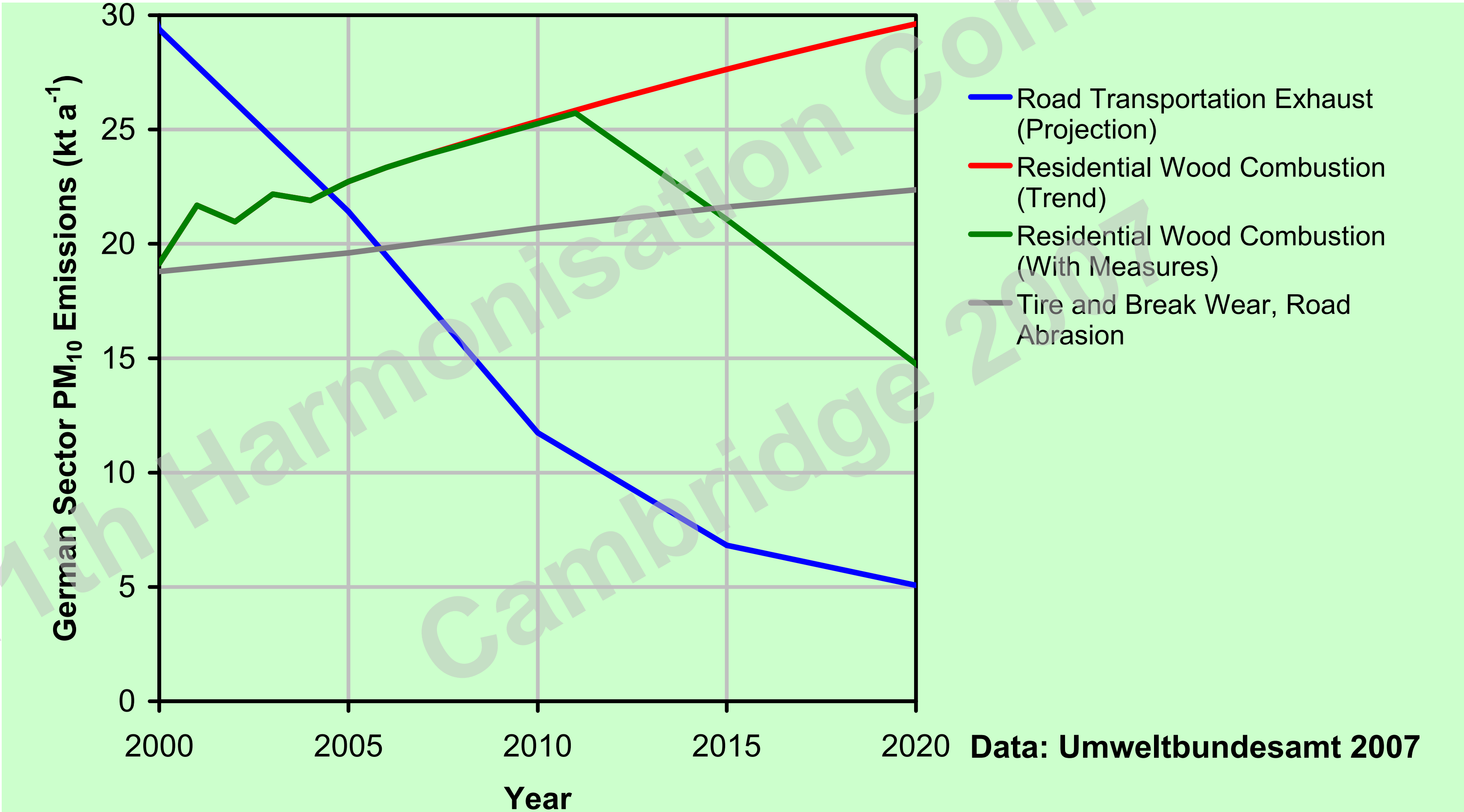
High PM_{10} Emissions



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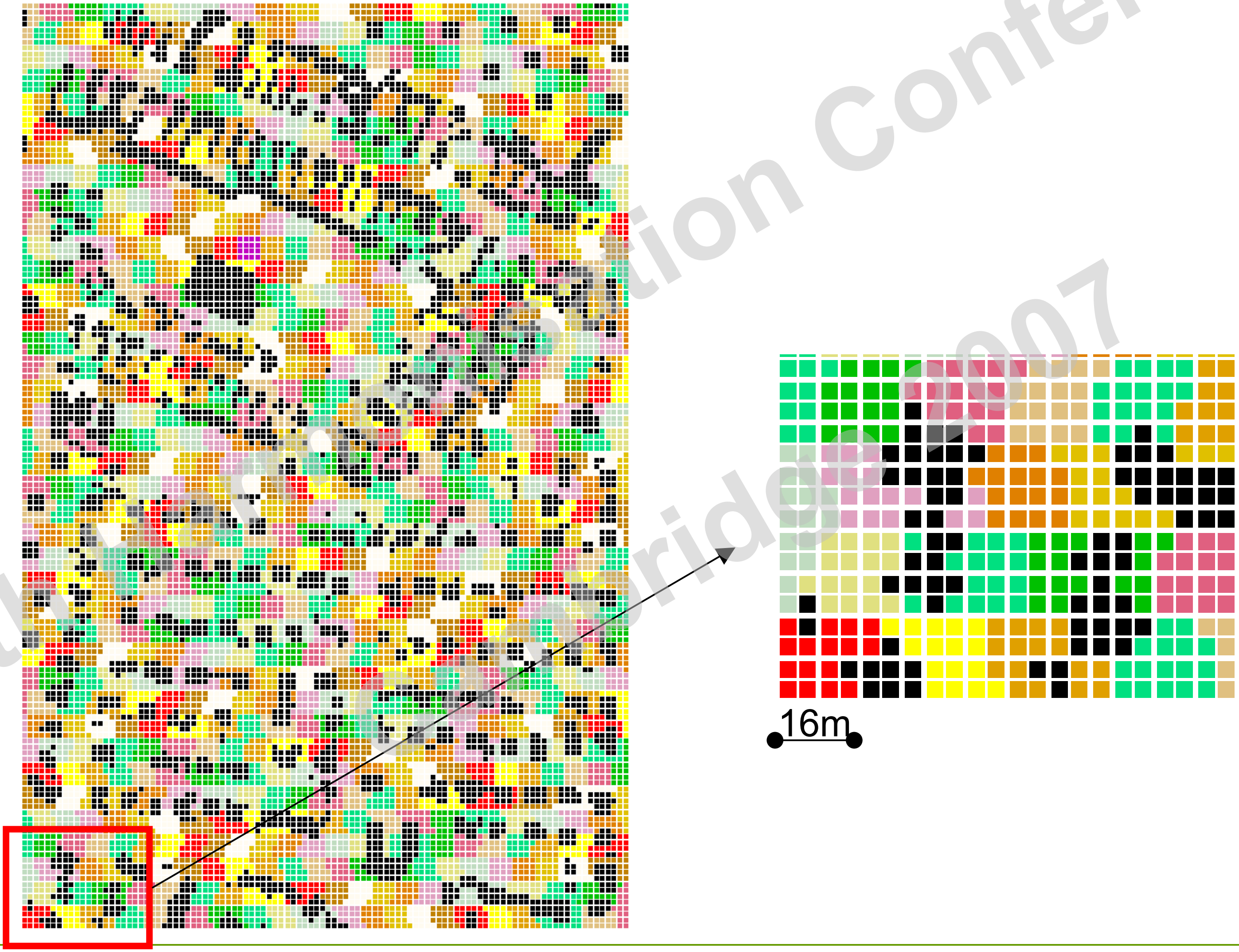
Assessment Areas



AUSTAL2000 Dispersion Model

AUSTAL2000 implements the Lagrangian particle model described by guideline VDI 3945 Part 3:

$$\boldsymbol{x}_{\text{new}} = \boldsymbol{x}_{\text{old}} + \tau(\boldsymbol{V} + \boldsymbol{u} + \boldsymbol{U})$$

- New position of particle
- Old position of particle
- Time step
- Mean wind velocity
- Turbulent velocity
- Additional velocity (e.g. plume rise)

$$\boldsymbol{u} = \boldsymbol{u}(\boldsymbol{\Sigma}, \mathbf{K})$$

- Variance of wind velocity fluctuations
- Diffusion coefficients

AUSTAL Interface to Flow Model

	Boundary layer model only	Boundary layer model + obstacle-increments	Micro-scale model
Mean velocity	√		√ *TALdia* Here: *MISCAM*
Velocity fluctuations	√ Here	√ *TALdia*	√
Diffusion coefficients	√ Here	√ *TALdia*	√

TALdia: Diagnostic meso- and micro-scale model, comes with AUSTAL2000

MISCAM: Prognostic micro-scale model,

- For this domain much faster than *TALdia*
- *Accounts for history of flow in complex structures*