Parametric study of the dispersion aspects in a Street Canyon area

Nektarios Koutsourakis
Panagiotis Neofytou
Alexander G. Venetsanos
John G. Bartzis

Environmental Research Laboratory NCSR DEMOKRITOS

Overview

- Scope of study
- Tool used for Numerical modelling
- Street-Canyon cases studied
- Conclusions

Scope of Study

In the framework of REVEAL and ROSE projects:

- Specifying of appropriate locations for measuring-instrument placement
  - Urban street-canyon measurement campaigns (Thessaloniki, Greece and Bremen, Germany)
  - Sensitivity threshold of instruments as regards to pollutant concentration (assurance of non-zero indications)

Numerical Modelling Tool

Computational Fluid Dynamics (CFD) code ADREA-HF:

- Solves both
  - the 3-D, time dependent RANS equations (equations for turbulent flow) in a given geometry using original anisotropic one-equation model for turbulence closure
  - the Mass Transfer equation of a pollutant in a given geometry
- Complex geometry (irregular terrain/man made structures) placed on Cartesian grid using Porosity formulation

Recent development: Incorporation of tunnels/cavities within an urban area

Thessaloniki case

Aristotelous square

Thessaloniki case

Mitropoleos street

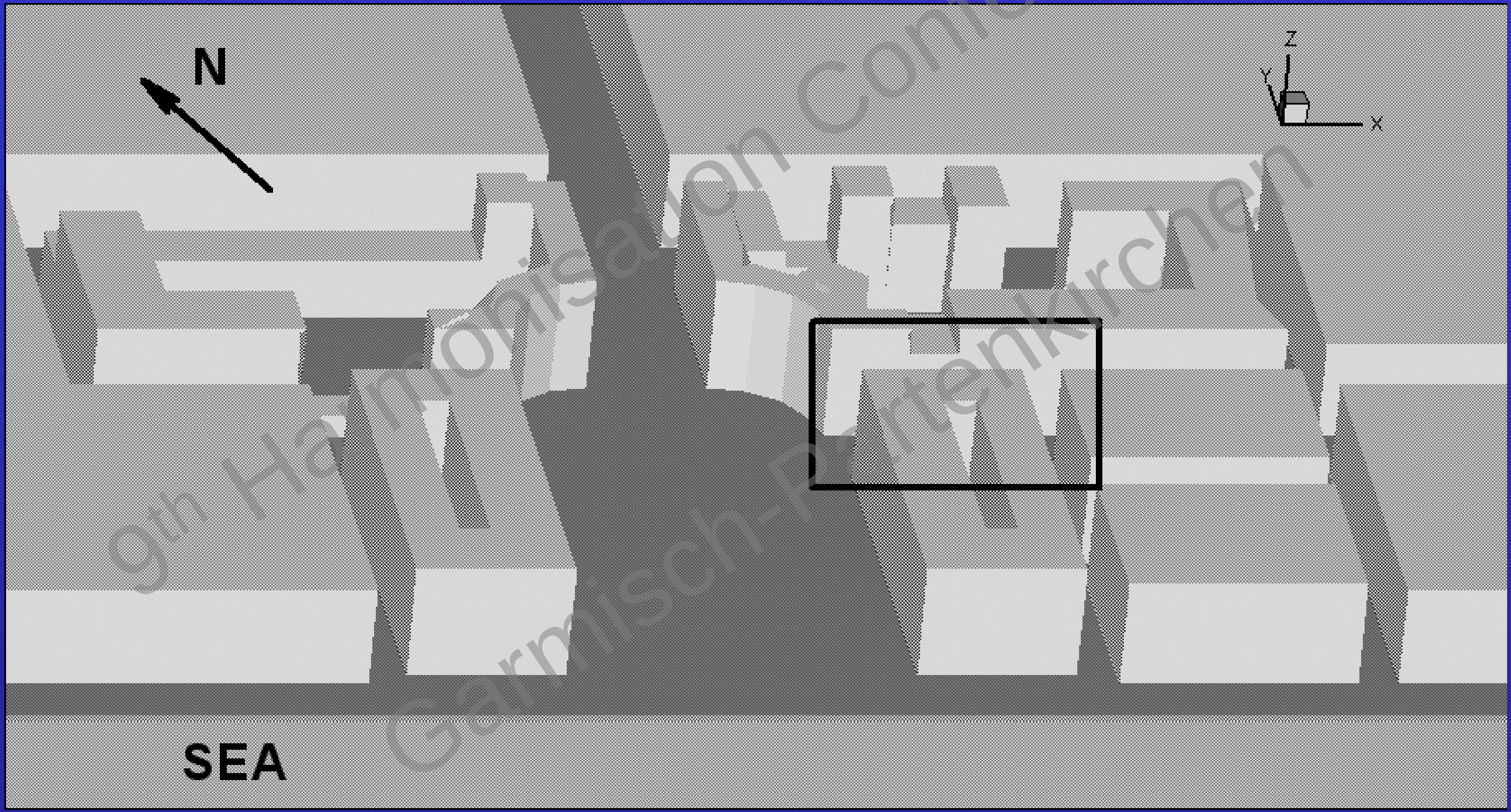
Thessaloniki case

modelling data

- Computational domain based on photographs of the area (Aristotelous Sq., Thessaloniki)
  - 736x763x180m area → 41x48x30 grid
  - Encompasses all buildings in the vicinity of the area
- Road modelled as uniform area source emitting with constant rate.
- Different wind directions/velocities studied
  - N, NW, NE, SW and SE directions, 3m/s
  - N direction, 3m/s, 5m/s

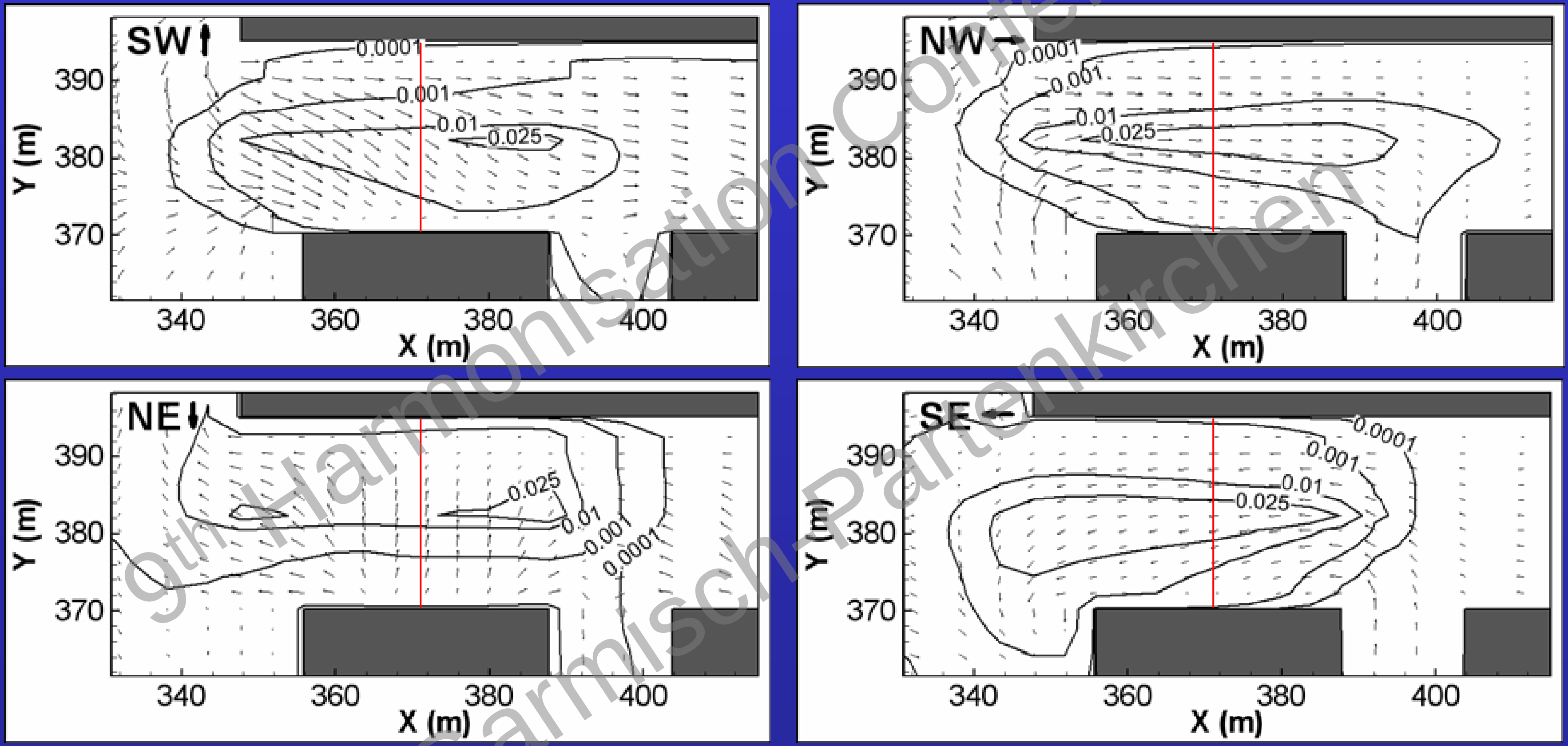
Thessaloniki case

geometry



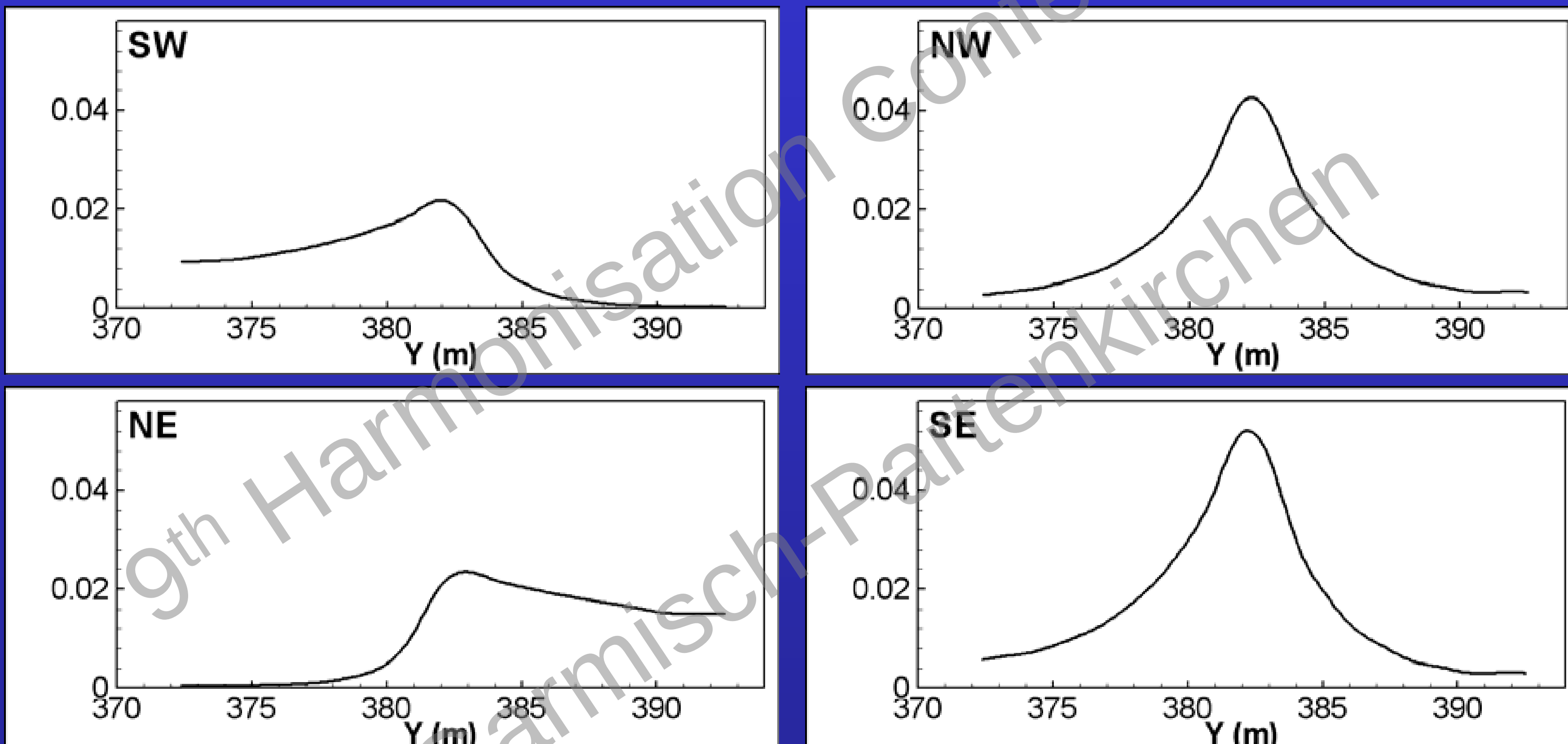
Thessaloniki case

Effects of wind direction: normalised (10^6ppm/Kg/s) concentration levels and flow field (z=0.5m)



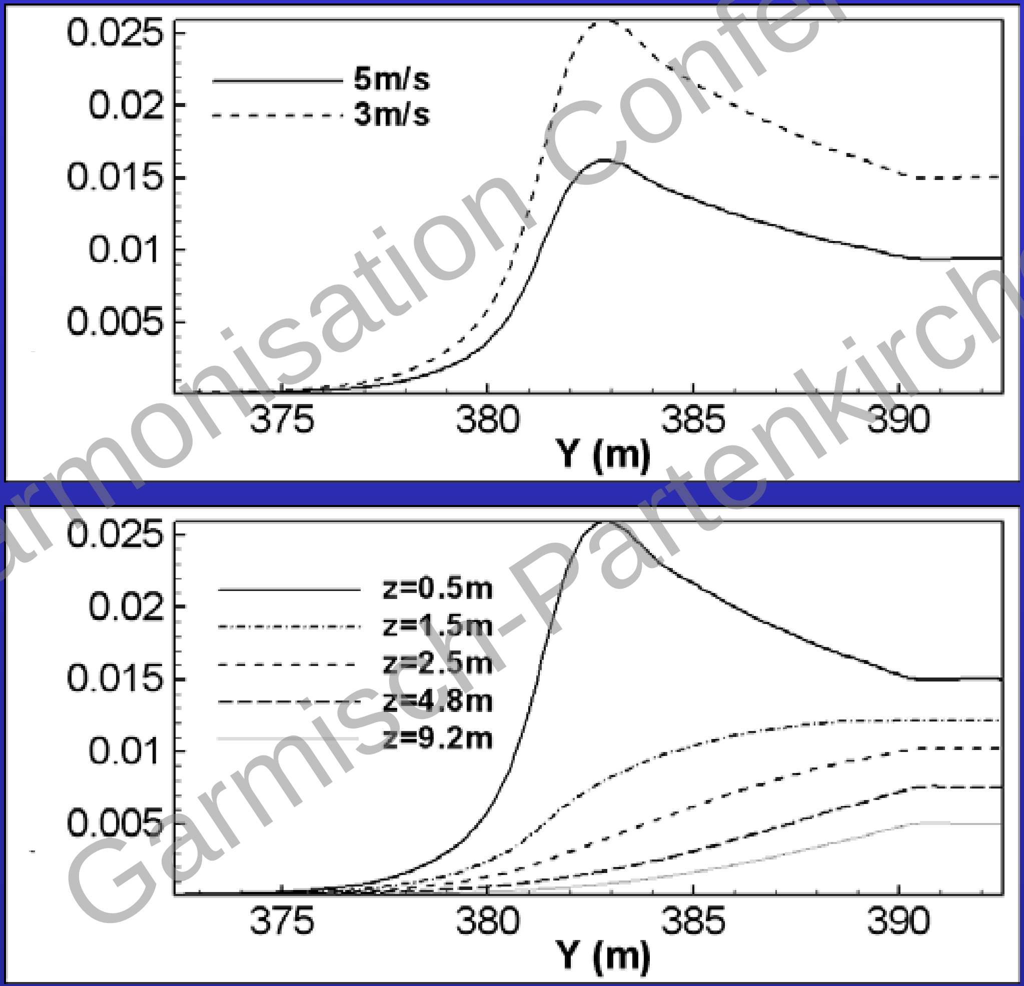
Thessaloniki case

Effects of wind direction: normalised (10^6ppm/Kg/s) concentration across street (z=0.5m)



Thessaloniki case

Effects of height and wind velocity: normalised (10^6ppm/Kg/s) concentration across street



Thessaloniki case

conclusions

- Height and high wind velocity reduces signal strength
- Vertical-to-the-street winds result in higher concentrations at the upwind side of the street
- Parallel-to-the-street winds result in higher concentrations at the vehicle level
- Presence of secondary streets can cause flow-splitting thus dispersing the pollutant in both directions $\Rightarrow$ positioning of beam in the centre of canyon not beneficial

Bremen case

modelling data

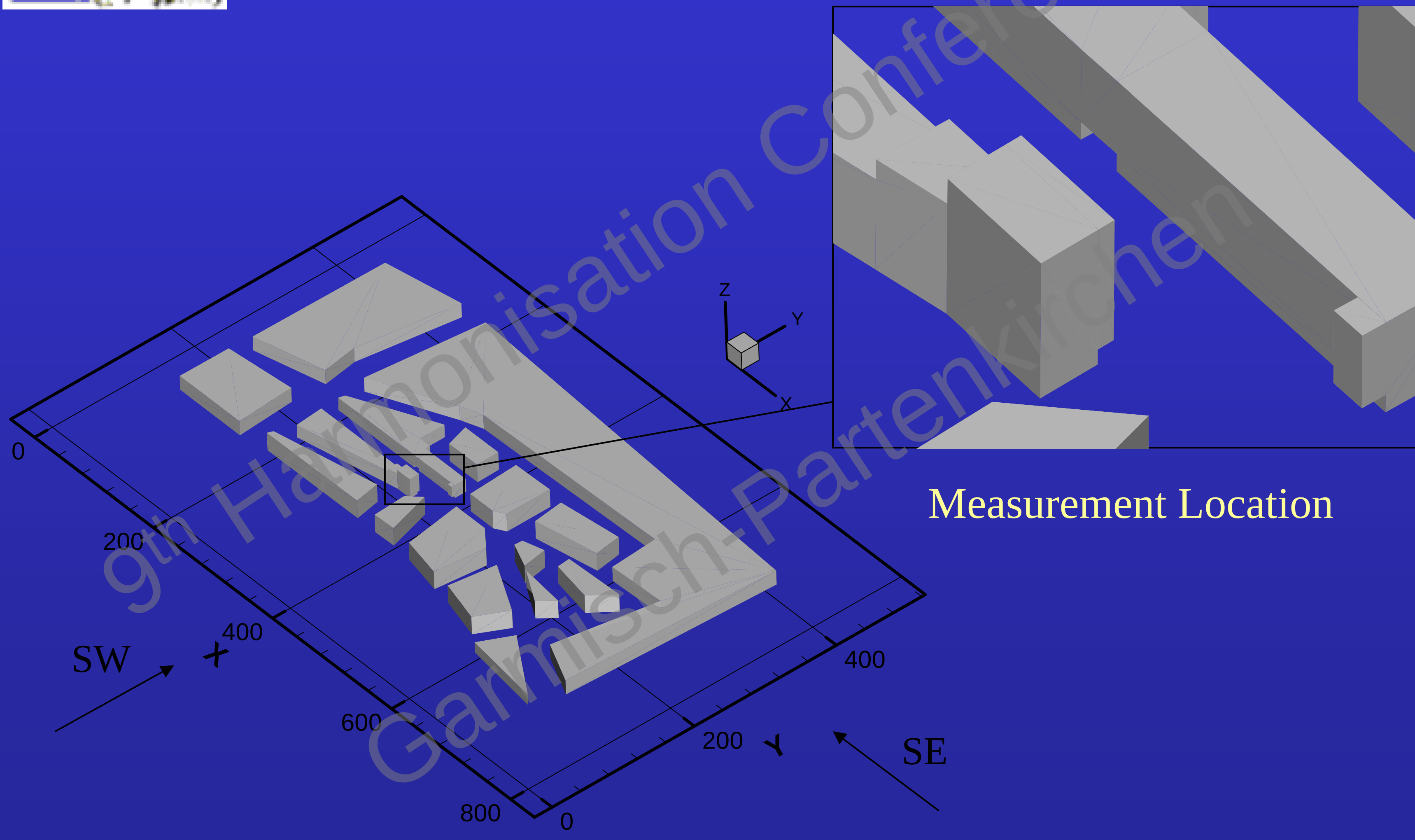
- Computational domain based on photographs of the area (Martinistr., Bremen, Germany)
  - 800x500x100m area $\rightarrow$ 62x40x25 grid (clustered near points of interest)
  - Encompasses all buildings in the vicinity of the area
- Road modelled as uniform area source emitting with constant rate.
- Dominant wind directions considered (according to the wind-rose of the area).
  - SW and SE directions, 9m/s

Bremen case

Martini street

Bremen case

geometry



Bremen case

beam-path study

Instruments consist of a source and reflector of beam along which the pollutant-concentration (C) is measured

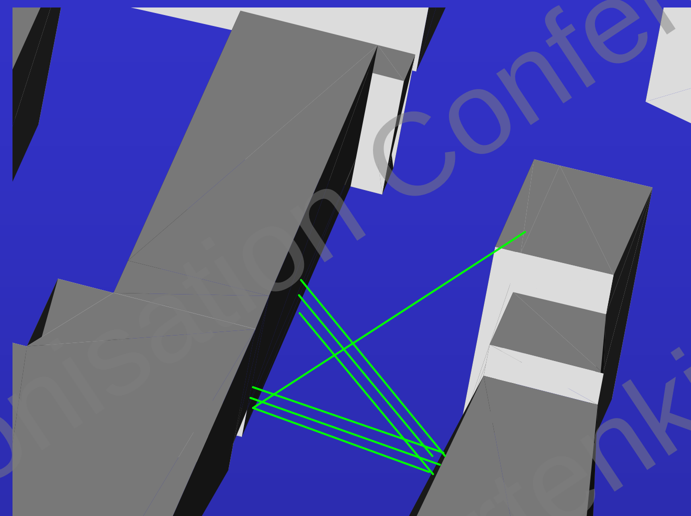
Parametric study

- Source, Reflector positions focusing on
  - Beam length (L)
  - Beam location

  so that C*L is sufficiently high
- Pollutant-concentration along beam

Bremen case

beam-path study

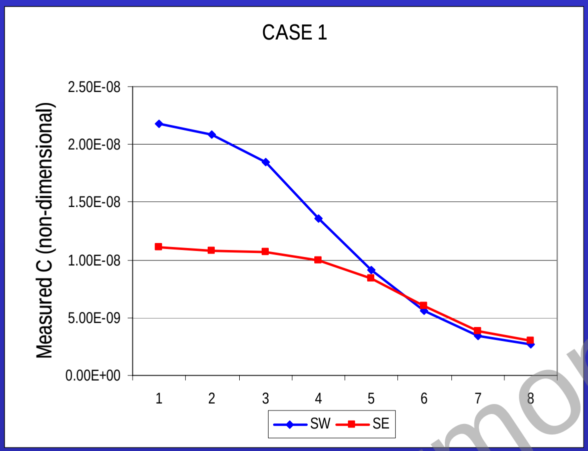


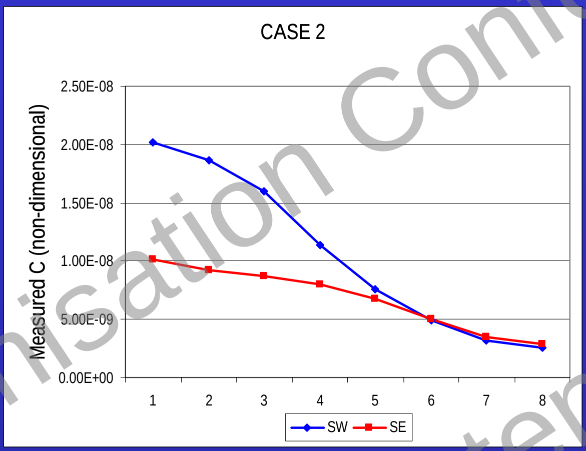
BEAM-PATHS	CASE No.	START (X, Y, Z) [m]			END (X, Y, Z) [m]			LENGTH [m]
HORIZONTAL BEAM OBLIQUE TO STREET	1	328	221	4	347	244	4	29.8
	2	328	221	5	347	244	5	29.8
	3	328	221	7	347	244	7	29.8
HORIZONTAL BEAM VERT. TO STREET	4	326	221	4	326	244	4	23
	5	326	221	5	326	244	5	23
	6	326	221	7	326	244	7	23
ROOF-1st FLOOR	7	341	222	25	347	244	4	31

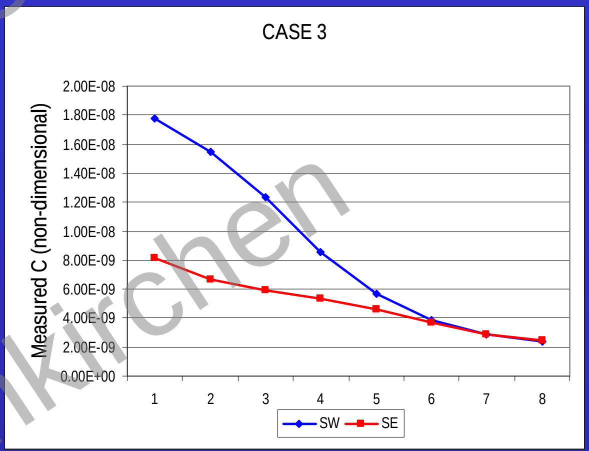
Bremen case

concentration levels

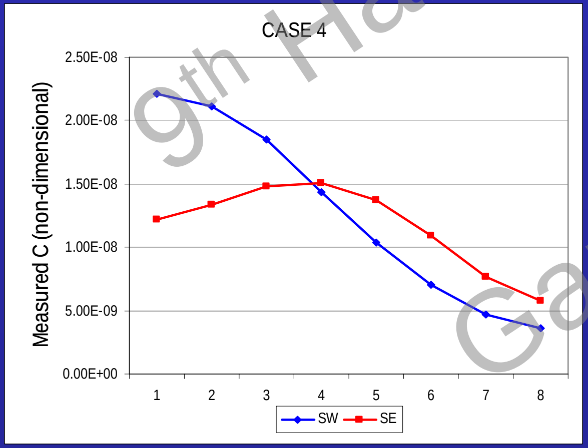
Beam-path oblique to street

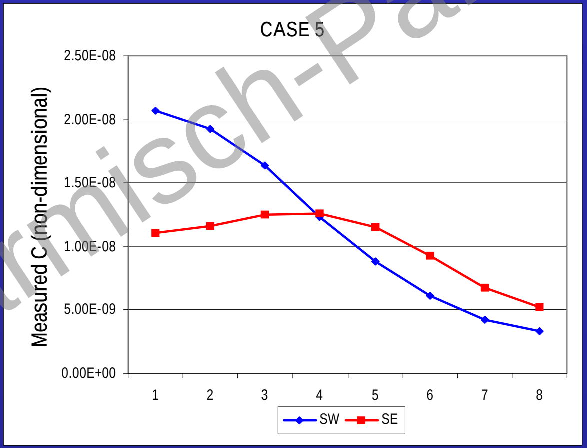


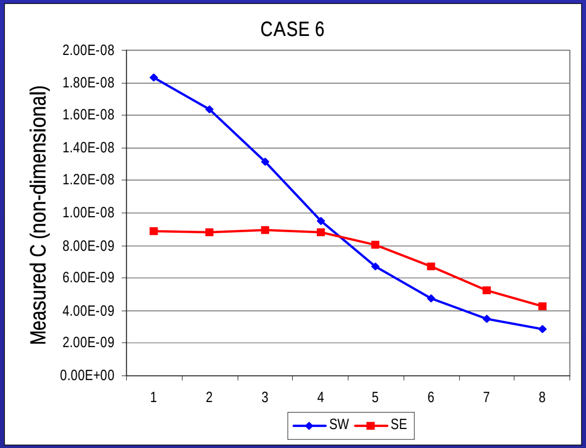




Beam-path vertical to street



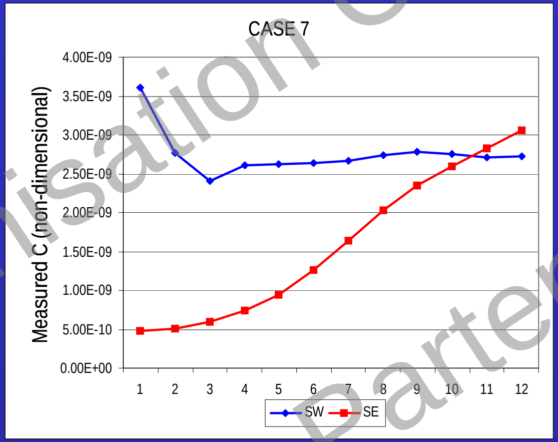




Bremen case

concentration levels

Beam-path: Roof-1st floor



	CASE No./ Normalised Concentration Levels						
Wind Dir.	1	2	3	4	5	6	7
SW	3.55e-7	3.12e-7	2.51e-7	2.92e-7	2.60e-7	2.12e-7	8.42e-8
SE	2.42e-7	2.03e-7	1.47e-7	2.78e-7	2.38e-7	1.74e-7	4.87e-8

Bremen case

conclusions

- Height reduces signal strength
- Oblique placement $\Rightarrow$ Wind-direction sensitivity of concentration levels
- Higher concentrations at the upwind side of the street
- Optimum placement: Beam vertical to street and close to the ground

Conclusions

- Height reduces signal strength
- Wind direction parallel to the street can induce higher concentrations for very low heights of beam-path position
- For positioning open-path measuring instruments:
  - Wind-direction sensitivity of concentration levels is to be taken into account
  - Flow-splitting phenomena can affect measurements
- Computational efficiency of ADREA-HF code for analysing effects of various parameters on the diffusion of a pollutant in a Street-Canyon area