AIR QUALITY ASSESMENT IN A STREET CANYON IN HELSINKI USING THE CFD MODEL ADREA-HF

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Overview of Presentation

- Scope of study
- Modelled Site
- Methodology
  - Numerical Modelling Tool
  - Wind speed/direction scenarios
- Results
  - Effects of different ambient wind speed/direction
  - Comparison with measurements
- Conclusions

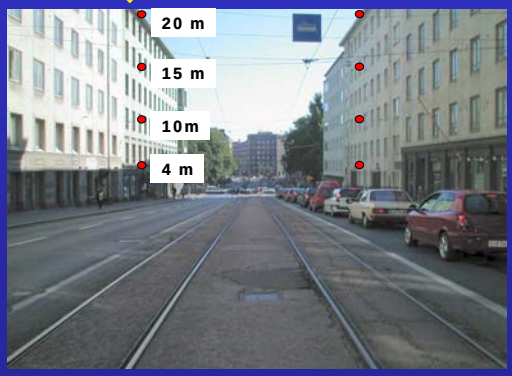
Scope of Study

To help local authorities responsible for the urban pollution control to understand the factors affecting on air quality in urban environments by

- Numerically determining pollution levels in a street canyon area in Helsinki, Finland using different wind speed/direction scenarios
- Comparing predictions with existing measurements

Runeberg Street-Canyon
site view

Runeberg street
View to the south



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Methodology
numerical modelling tool

Computational Fluid Dynamics (CFD) code

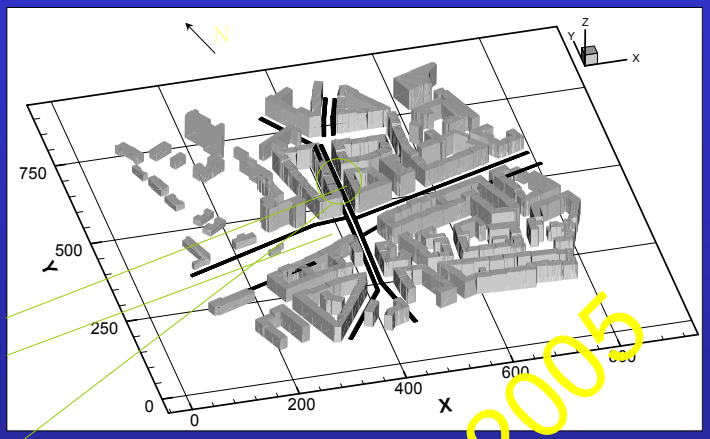
- ADREA-HF

  Solves both
  - the 3-D, time dependent RANS equations (equations for turbulent flow) in a given geometry
  - the Mass Transfer equation of a pollutant in a given geometry

Methodology
numerical method

- Computational domain constructed employing DELTA-B pre-processor from actual coordinates provided by the Helsinki Metropolitan Area Council
  - 900x900x180m area → 78x65x35 grid (refined near Runeberg street)
  - Includes all buildings in the vicinity of the area
- Boundary conditions
  - Zero gradient and given value at inflow; zero gradient at the outflow; wall functions for velocity on solid surfaces
  - Road lanes modelled as uniform area sources emitting with constant rate
  - Wind speed/direction conditions taken from measurements that took place at the roof level in Runeberg Street

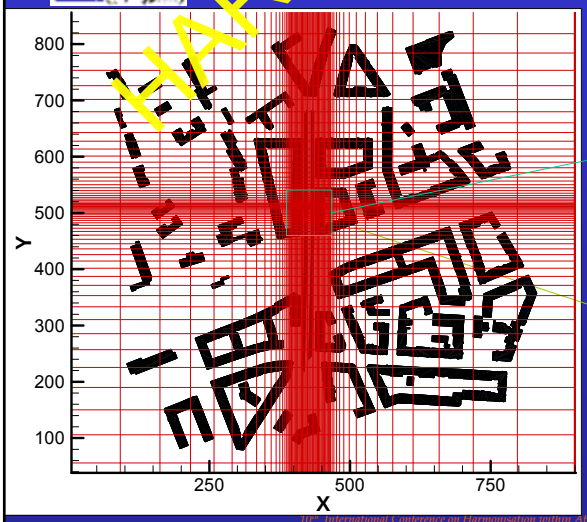
Methodology
computational domain

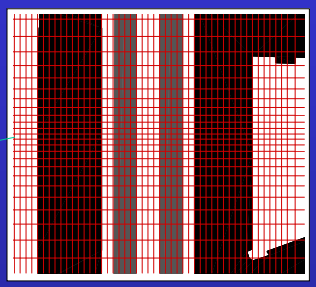


Runeberg str.
Hesperian str.

Location of receptor points

Methodology
grid





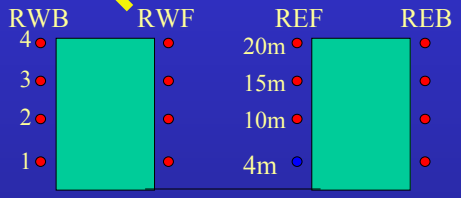
refinement near
receptor points

Methodology
input data

- Measurement campaign:
  - Street level air quality measurements of NOx and on-site electronic traffic counts
  - Wind speed/direction measurements at roof level in Runeberg Street
  - Time resolution of measurements: 1min
  - Background concentration ~ 55 μg/m^3
- NOx emission from Runeberg street traffic assumed at 30.52 μg/m^2/s: Typical daytime traffic of 1200 vehicles/hour
- 4 groups of 4 receptors assumed: each group with same x,y coordinates with receptors at 4, 10, 15 and 20m
- Wind directions/speeds: 2 groups corresponding to 1m/s and 3 m/s of 4 cases corresponding to easterly, westerly, northerly and southerly wind directions
- Measured concentrations (C_{meas}) equalised so as to correspond to traffic volume (TV) of 1200 vehicles/hour according to $C_{eq}=(TV_{1200}/TV_{meas})C_{meas}$

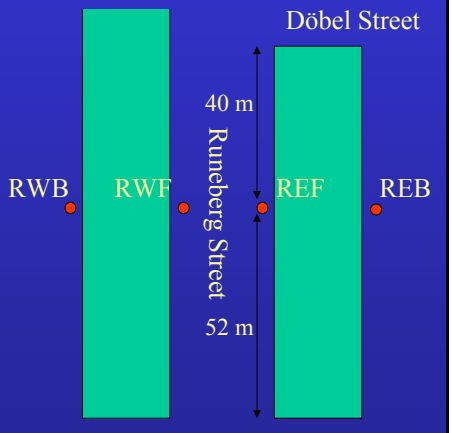
Methodology
topology of receptor points

Vertical cross-section

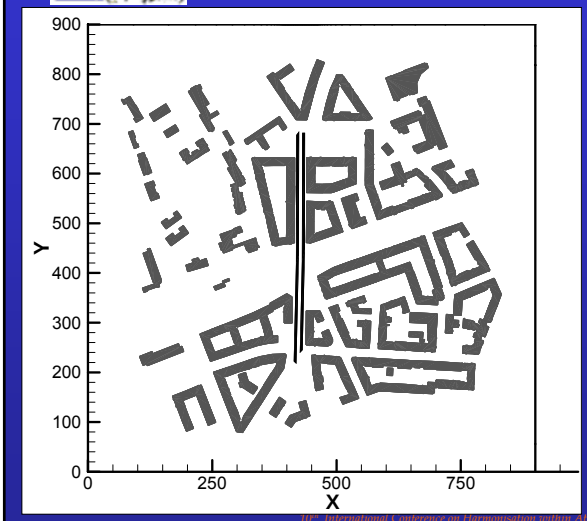


air quality monitoring station AND receptor point

Horizontal cross-section



Methodology
wind directions



Northerly WD
(-6 deg*)

Westerly WD
(264 deg*)

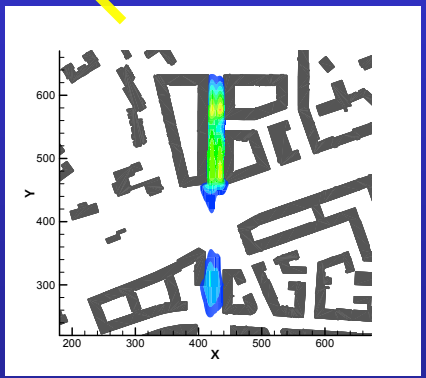
Easterly WD
(84 deg*)

Southerly WD
(174 deg*)

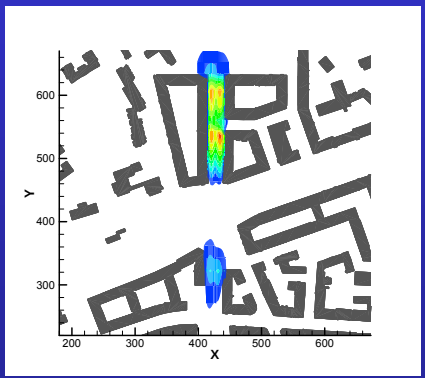
*coordinate system of computational domain

Results
concentration field for u=3m/s (z=4m)

WD: northerly (-6^0)

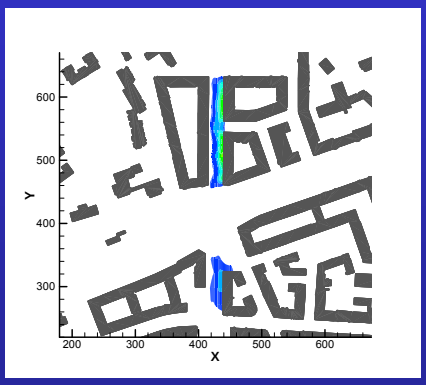


WD: southerly (264^0)

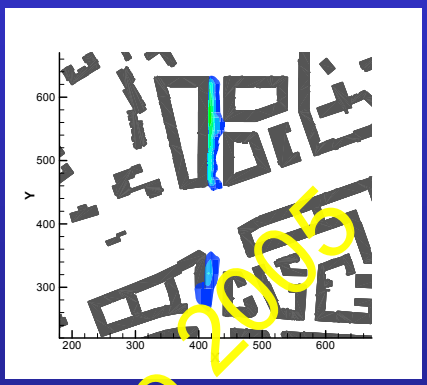


Results
concentration field for u=3m/s (z=4m)

WD: easterly (84⁰) ←



WD: westerly (264⁰) →



Results
Predicted NOx concentration [μg/m³] at receptors within the canyon

Case	WS (m/s)	WD (deg)	REF1	REF2	REF3	REF4	RWF1	RWF2	RWF3	RWF4
1	1	-6	393.9	157.5	62.5	14.4	367.8	169.3	72.3	18.6
2	1	174	391.5	168.4	73.0	21.8	364.1	157.8	67.3	19.8
3	1	84	414.2	284.4	227.1	141.2	24.5	16.6	14.8	11.3
4	1	264	14.5	10.8	9.7	7.0	264.2	182.0	156.7	84.5
5	3	-6	123.3	48.2	19.1	4.6	124.4	58.7	25.6	6.7
6	3	174	127.4	55.4	24.6	7.7	115.7	49.7	21.2	6.4
7	3	84	137.3	93.6	74.1	46.4	8.0	5.2	4.6	3.5
8	3	264	4.2	3.1	2.8	2.0	82.2	56.5	48.8	27.0

Results

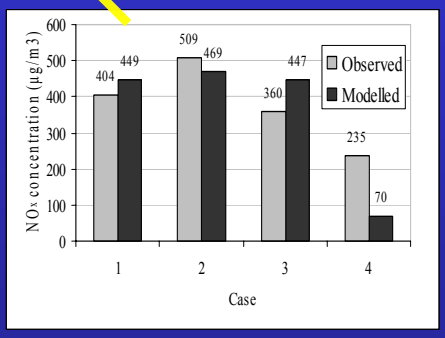
Predicted NOx concentration [μg/m³] at receptors behind canyon-buildings

Case	WS (m/s)	WD (deg)	REB1	REB2	REB3	REB4	RWB1	RWB2	RWB3	RWB4
1	1	-6	1.8	1.8	1.9	2.0	2.2	2.1	2.2	2.4
2	1	174	4.4	4.5	4.6	4.7	3.9	4.1	4.3	4.4
3	1	84	0.1	0.1	0.1	0.1	6.3	6.4	6.6	7.5
4	1	264	4.0	4.0	4.0	4.2	0.1	0.1	0.1	0.1
5	3	-6	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.0
6	3	174	1.7	1.7	1.7	1.7	1.5	1.6	1.6	1.7
7	3	84	0.0	0.0	0.0	0.0	1.9	1.9	2.0	2.3
8	3	264	0.9	1.0	1.0	1.0	0.0	0.0	0.0	0.0

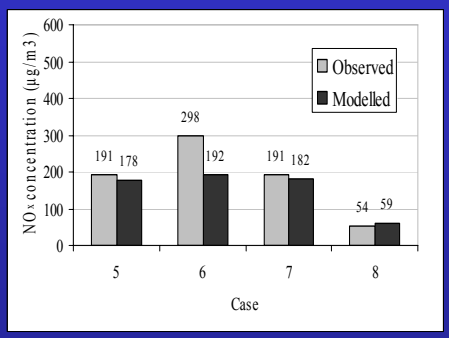
Results

Prediction-measurement comparison at receptor REF1

u=1 m/s



u=3 m/s



Conclusions

- The dependency of concentration levels on the wind direction is more pronounced for higher wind speeds
- Concentration levels decrease with height for all cases
- Concentration levels for parallel-to-the-street-canyon winds are nearly the same for low receptor locations
- Low-height upwind in-canyon concentrations for perpendicular-to-the-street wind directions drop with the same rate for both wind speed cases. The same yields for parallel-to-the-street wind directions
- On the basis of numerical results, the influence of Runeberg street on the air-quality behind the street-canyon buildings is negligible compared to the background levels
- Numerical results show a satisfactory agreement with available measurements