COMPUTATIONAL MODELLING OF AIRFLOW IN URBAN STREET CANYON AND COMPARISON WITH MEASUREMENTS

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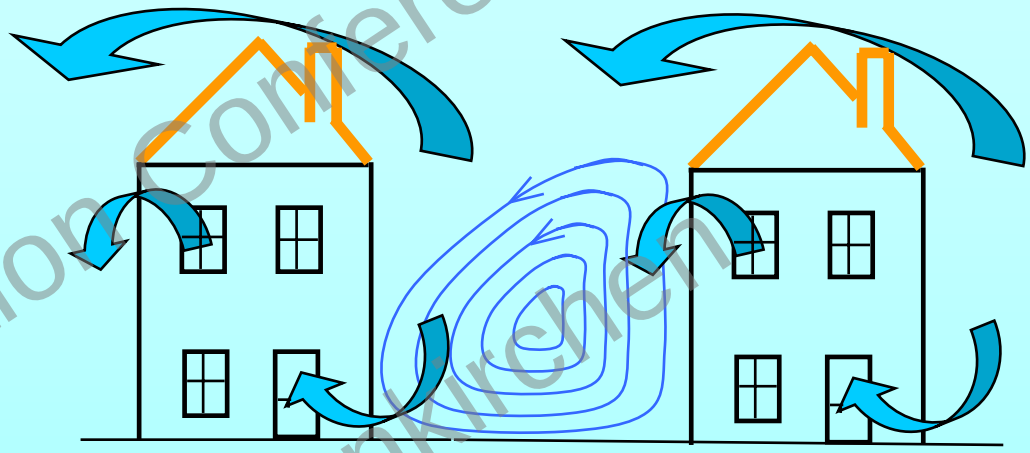
INTRODUCTION

Residential buildings in cities use different systems of ventilation

- **windows opening**
- **hybrid systems**



Hybrid systems are gaining more attention as they promise to be energy effective with a good control of indoor air quality

Operation of hybrid ventilation systems is significantly influenced by airflow in street canyons

It is necessary to obtain detail information on airflow field fore predominant wind conditions

AIR FLOW IN STREET CANYON

Knowledge of airflow is a prerequisite for a good function of hybrid systems

Information on airflow in a street canyon can be obtain from:

field measurement

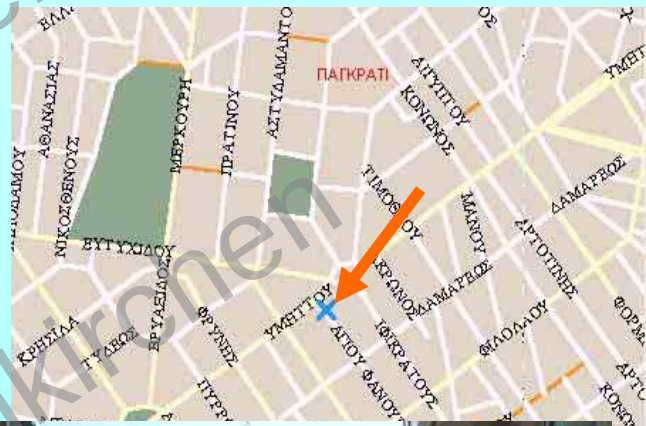
- exact results
- obtained results valid only for limited area
- necessity of long term measurement

modeling (CFD)

- provides 3D air flow field in a solved areas
- substitutes long time measurement
- necessity of validation

DESCRIPTION OF THE SOLVED AREA

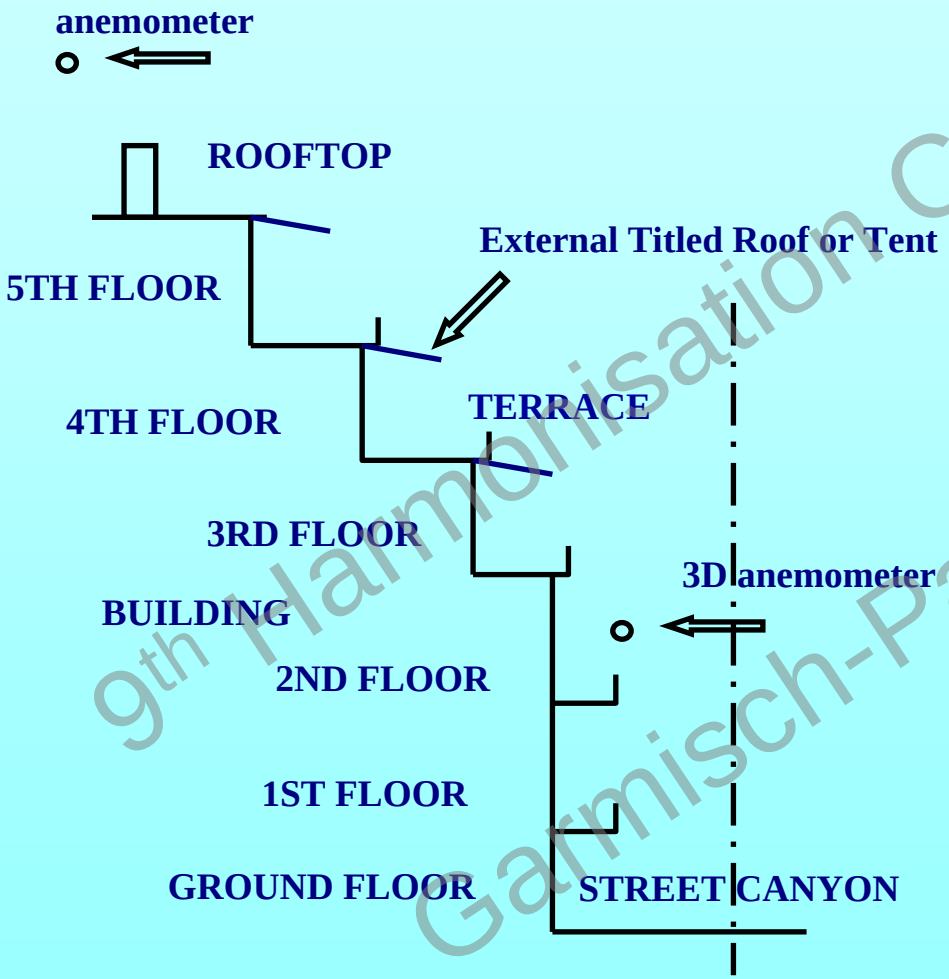
Agiou Fanouriou street canyon in Athens was chosen as a test canyon for comparison of modeling and field measurements



- The street canyon is located in residential part of city of Athens
- Tall buildings form the street canyon on both sides
- No trees are existing inside or nearby the canyon
- Balconies disturb facades on both sides.
- The canyon is part of regular perpendicular net of street canyons

DESCRIPTION OF THE SOLVED AREA

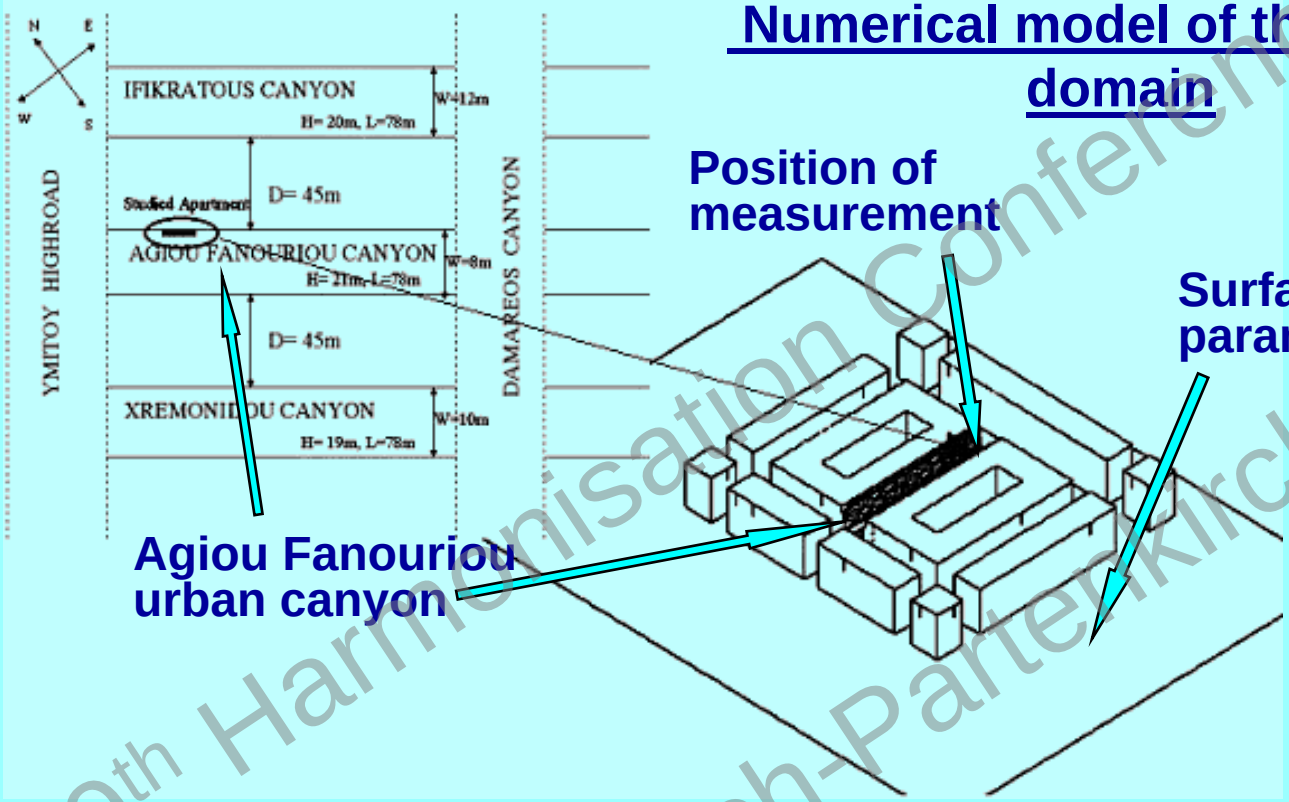
Sketch of the building's façade at Agiou Fanouriou urban canyon



- two floors above ground with plane façade
- terraces form other tree floors of the building
- building roof is flat
- buildings on both sides are same geometry
- shade makers taken into account

DESCRIPTION OF THE SOLVED AREA

Numerical model of the solved domain



- The canyon has a NW-SE orientation and its main axis is 137 degrees from the North.
- The canyon's length is 78m, its width is 8m and the average height of buildings is 21m.
- Surrounded urban area is formed by regular net of street canyons, intersecting perpendicularly.

MATHEMATICAL DESCRIPTION

Two ways of airflow mmodeling in street canyons

Steady situation

We solve airflow for predominant wind conditions

- steady wind velocity
- steady wind direction

Used for CFD calculation of the studied canyon

Transient situation

Transient wind conditions serve for setting of transient boundary conditions

- detail record of meteorological conditions

transient wind direction

transient wind velocity

- great demand on hardware capacity

Set of differential equations for conservation of mass and momentum was solved for steady turbulent incompressible flow. The governing equations for the continuous phase with a general variable ϕ:

$$\frac{\partial}{\partial t}(\rho\phi)+\frac{\partial}{\partial x_i}(\rho u_i\phi)=\frac{\partial}{\partial x_i}\left(\Gamma_{ef}\frac{\partial\phi}{\partial x_i}\right)+S_\phi$$

Boundary conditions

The numerical model represents only part of actual urban area

↓

Boundary conditions must advisably substitute
- - influence of surrounded area
- W - wind conditions

↓

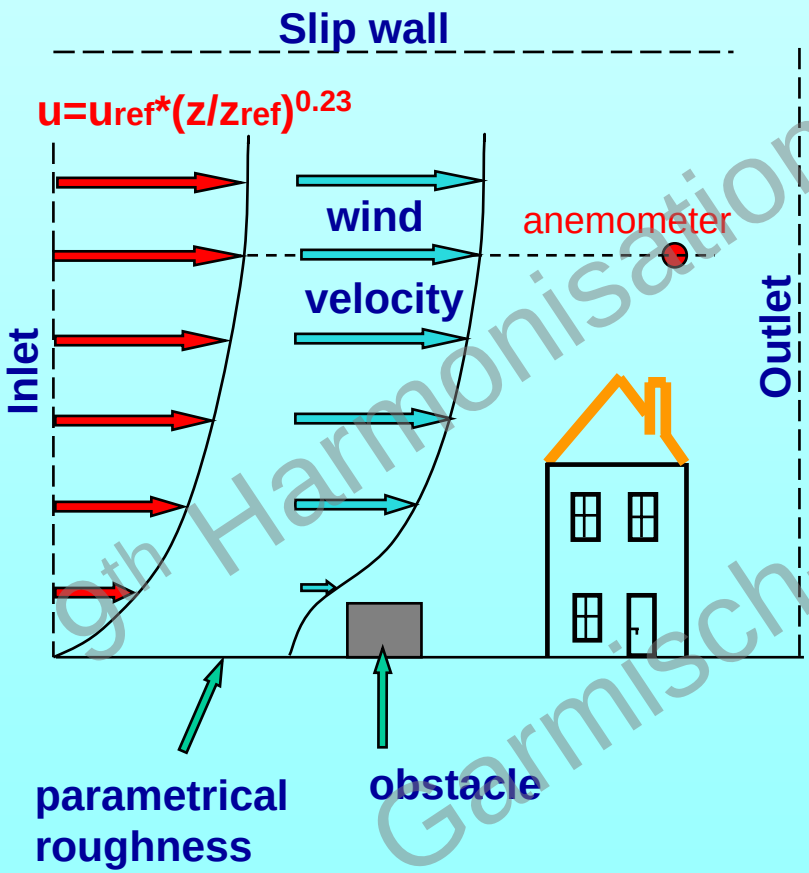
Wind velocity and wind direction were set in two different ways

↙ ↘

“wind velocity layer” „wind velocity profile“

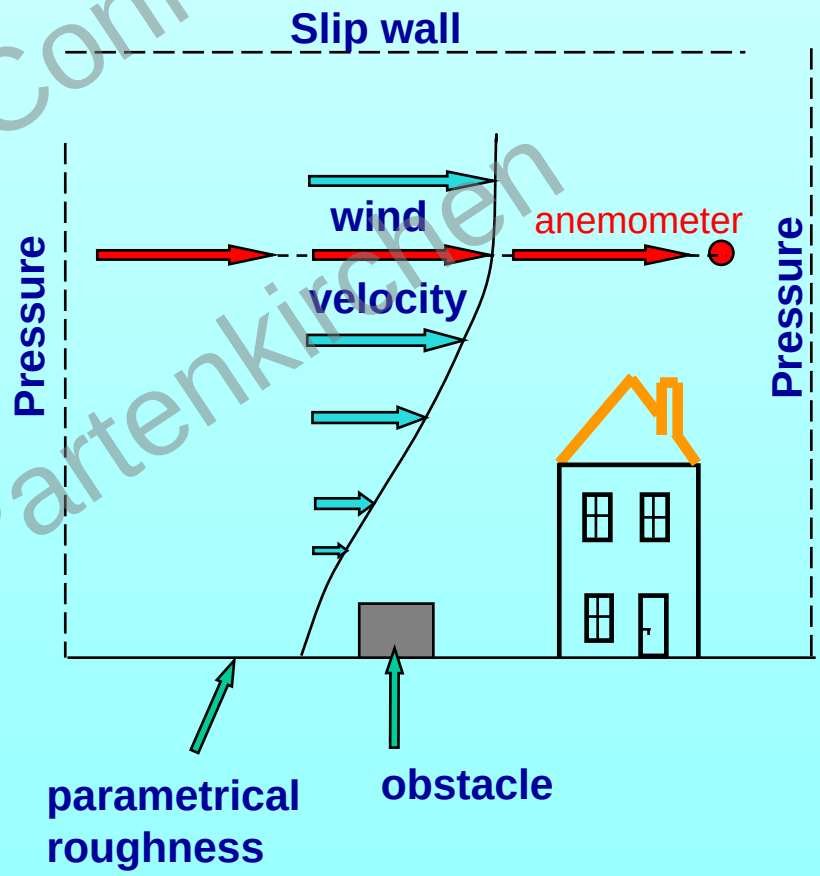
BOUNDARY CONDITIONS

„wind velocity profile“



Air velocity profile prescribed
at incoming air boundary faces

“wind velocity layer”



Air velocity prescribed at
a corresponding air layer

NUMERIC SIMULATION

Air velocity fields were solved for these configurations

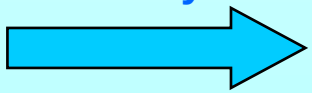
boundary conditions: wind velocity	model of turbulence	wind direction
„wind velocity profile“		
wind velocity 3 m/s wind velocity 6 m/s	K-ε HiRe K-ε RNG K-ε LoRe	longitudinal oblique perpendicular
„wind velocity layer“		
wind velocity 3 m/s wind velocity 6 m/s	K-ε HiRe K-ε RNG K-ε LoRe	longitudinal oblique perpendicular

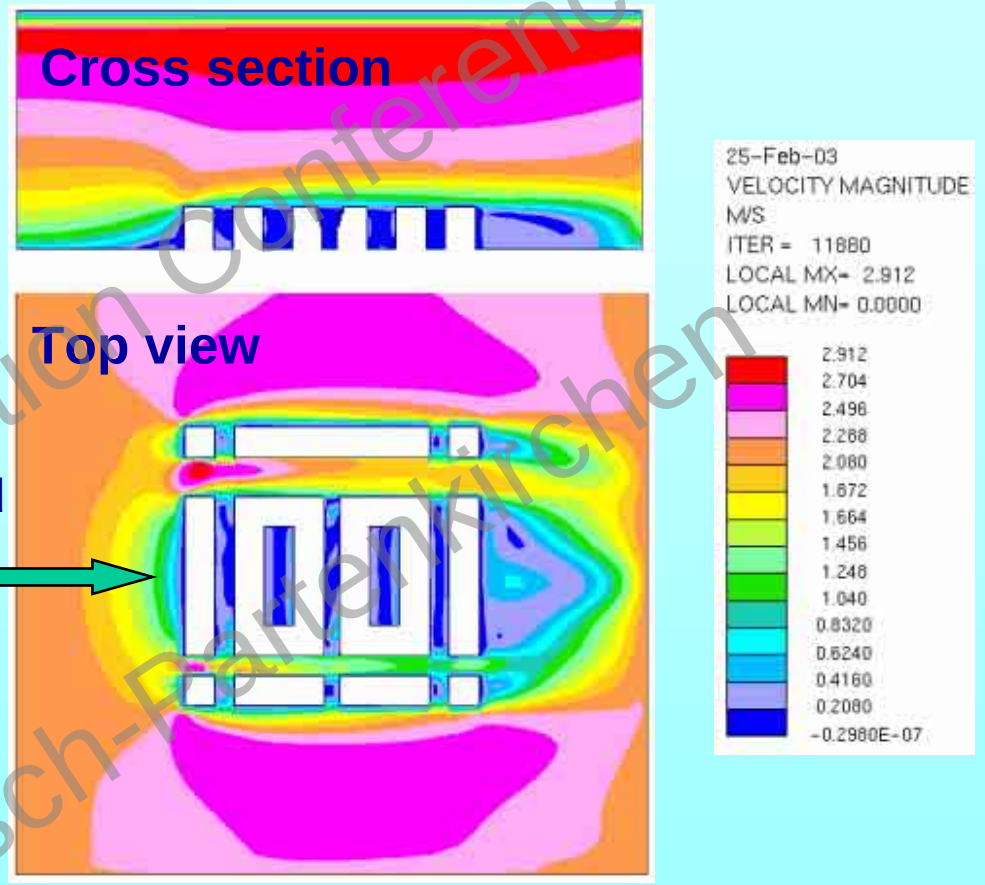
36 configurations were solved and compared with measurement

Air velocity field

Perpendicular wind direction

Wind velocity 3 m/s





Interaction of undisturbed wind velocity profile with first modeled buildings strongly influences a terminal airflow pattern

- Geometry of calculated area is the most important parameter forming final air velocity field
- If a street canyon is oriented at same direction as wind blows then major quantity of air pass throw this canyon and perpendicular canyons are without intensive longitudinal air motion

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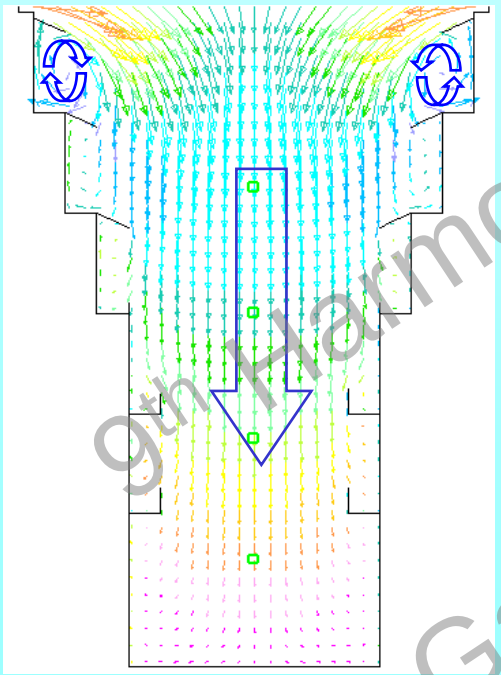
Wind velocity fields at cross section of the street canyon

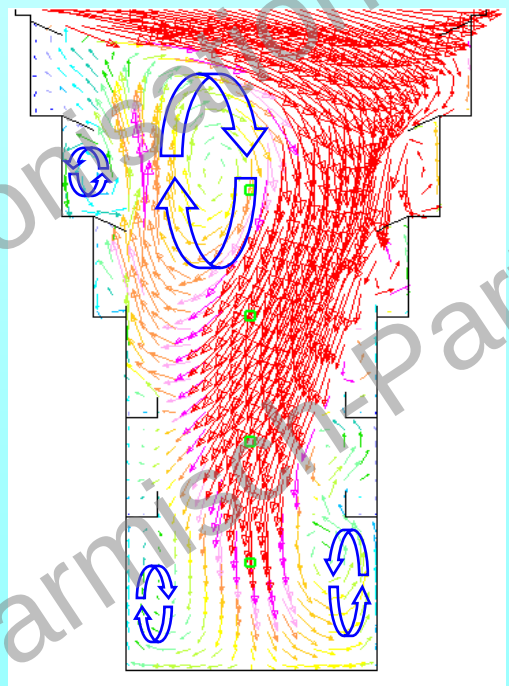
K-ε LoRe

Wind direction:

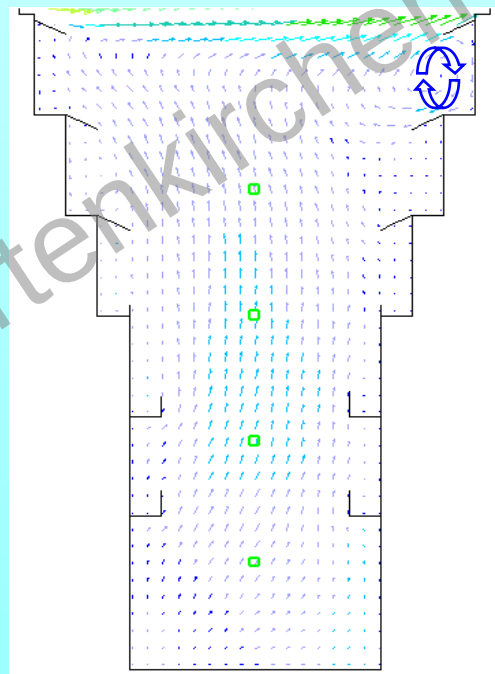
longitudinal

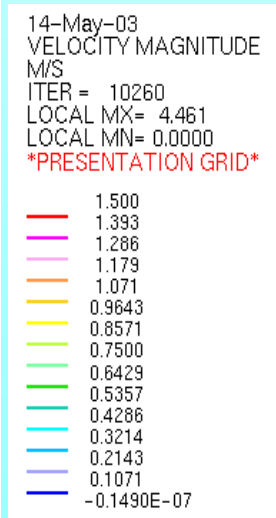


oblique



perpendicular





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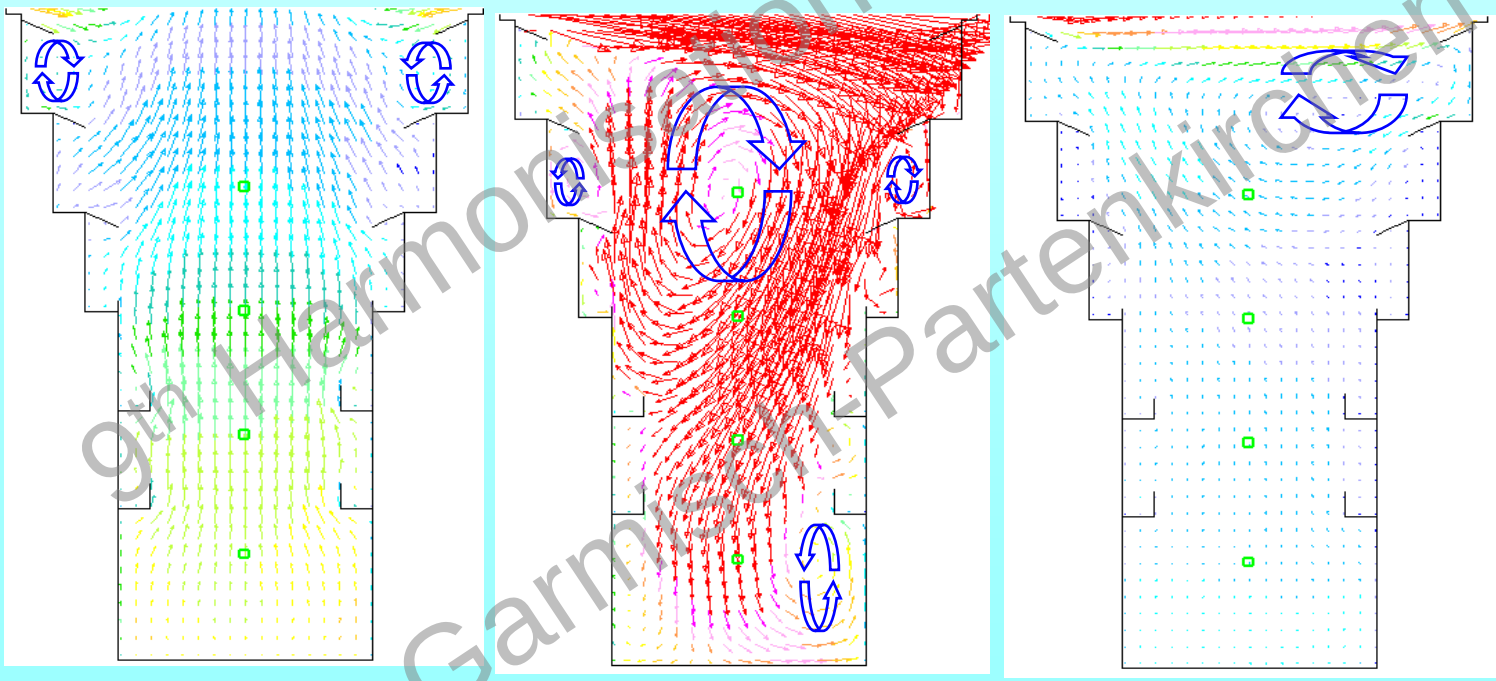
Wind velocity fields at cross section of the street canyon

K-ε HiRe

Wind direction:

longitudinal **oblique** **perpendicular**



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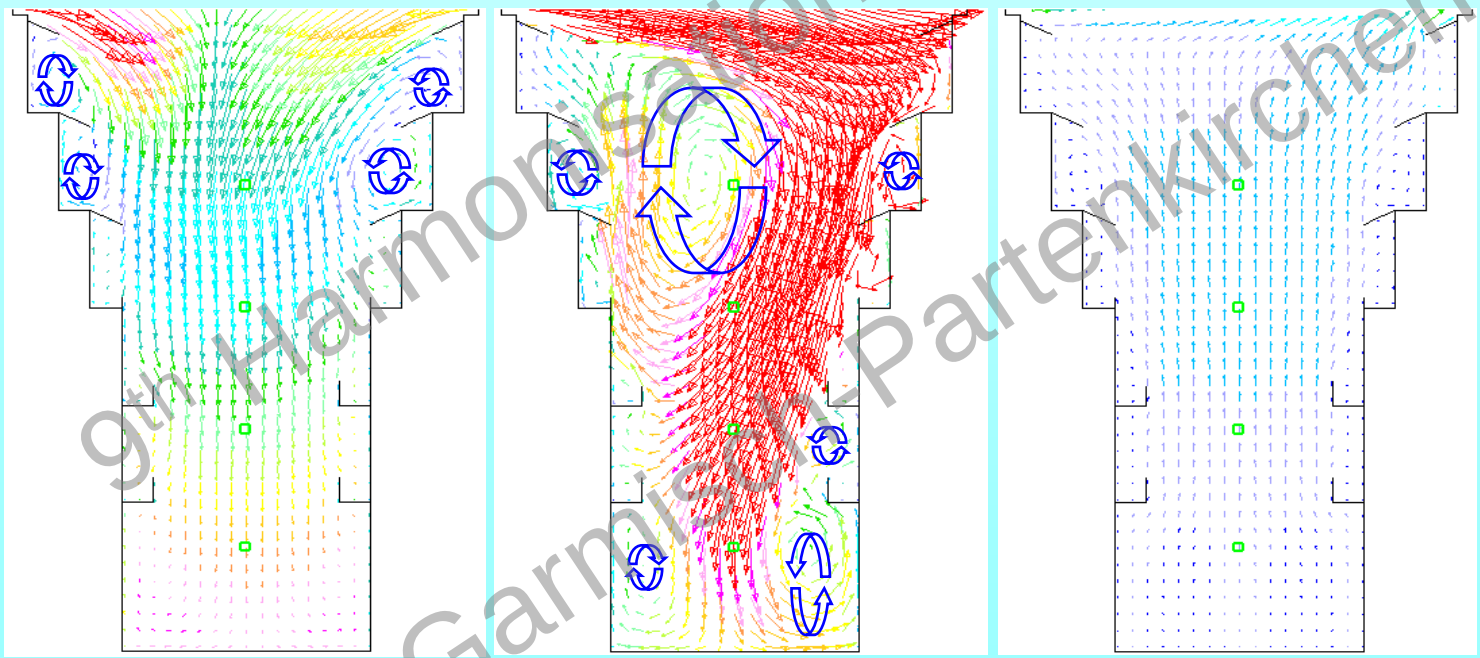
Wind velocity fields at cross section of the street canyon

K-ε RNG

Wind direction:

longitudinal **oblique** **perpendicular**



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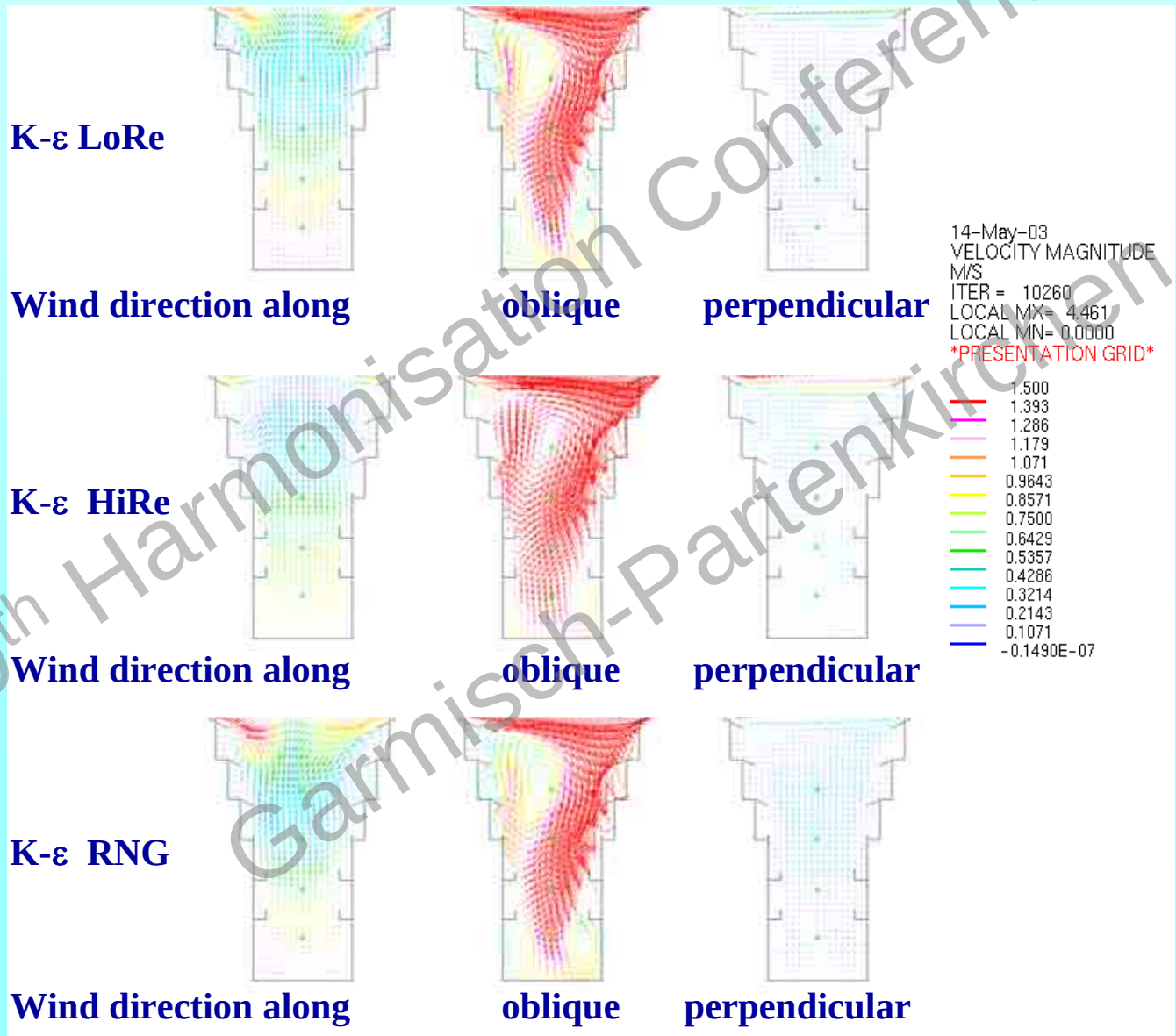
Velocity fields at cross section

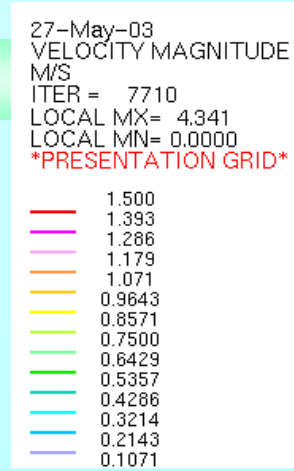
- wind velocity 3m/s



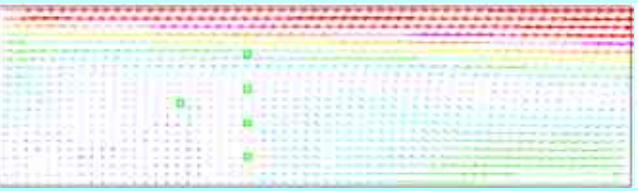
RESULTS

Velocity fields at longitudinal central section of the street canyon

- wind velocity 3m/s



K-ε LoRe

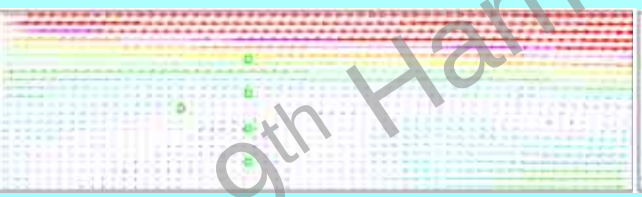


Wind direction along

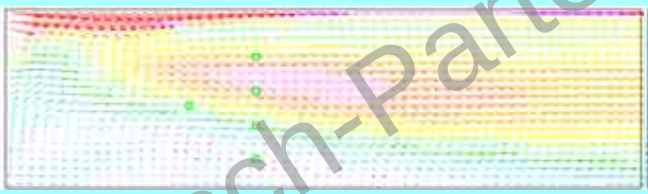
oblique

perpendicular

K-ε HiRe



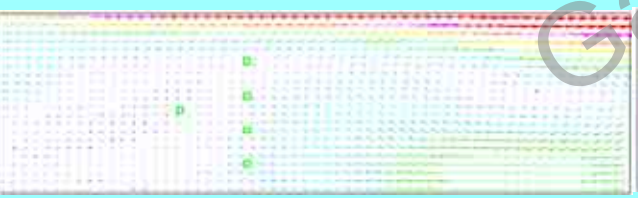
Wind direction along



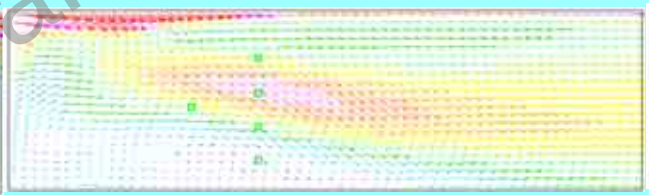
oblique

perpendicular

K-ε RNG



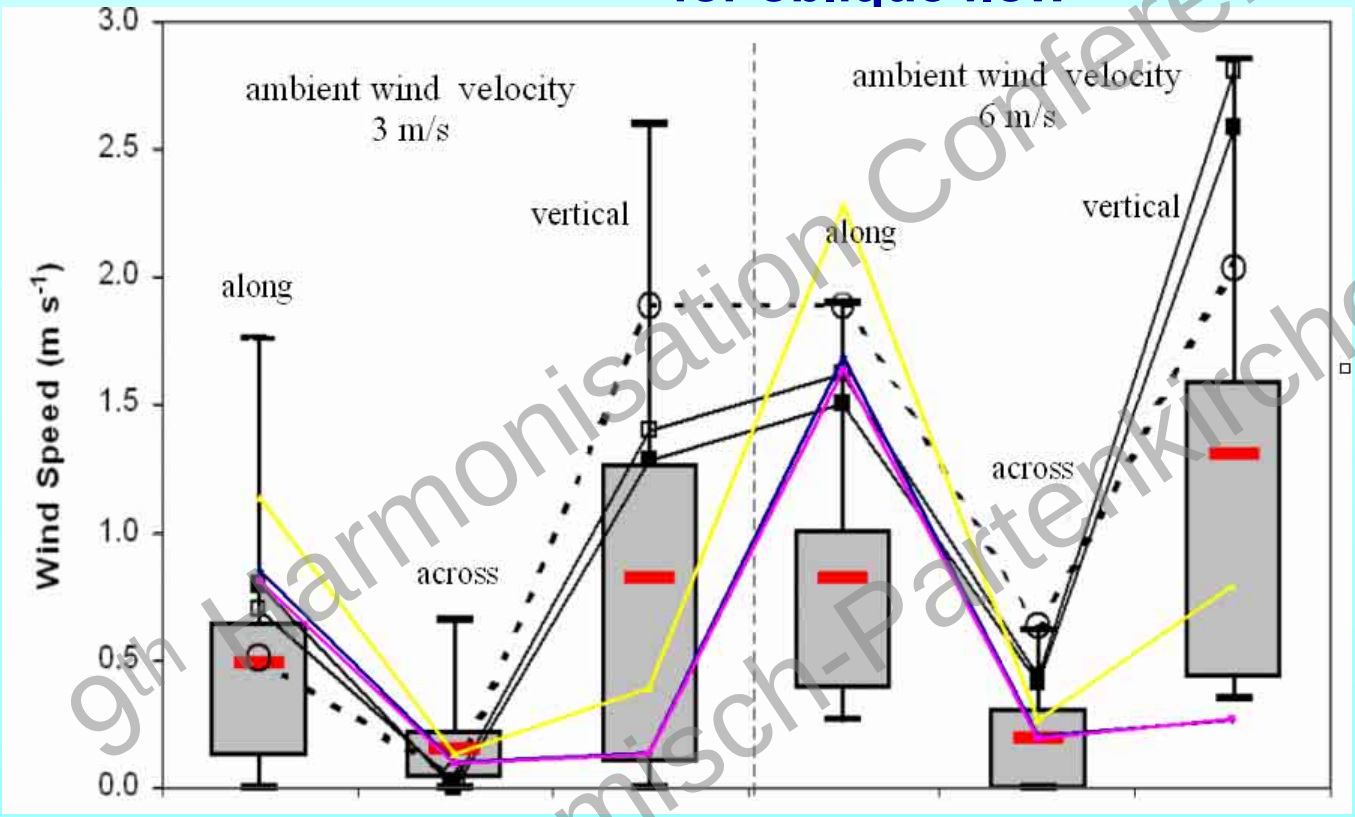
Wind direction along

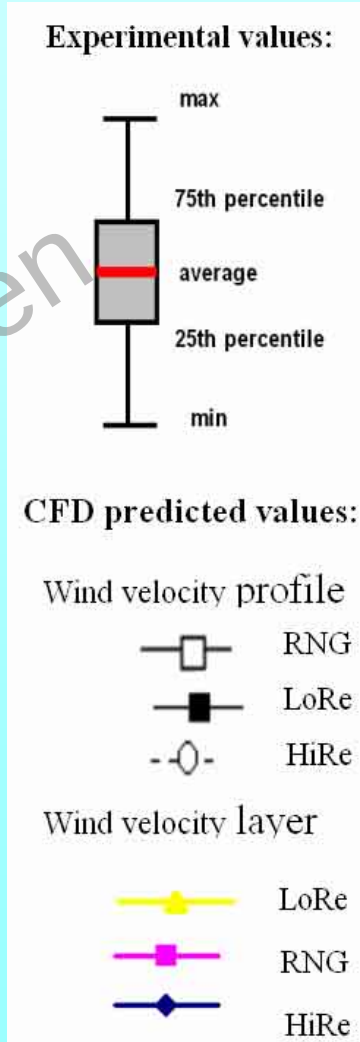


oblique

perpendicular

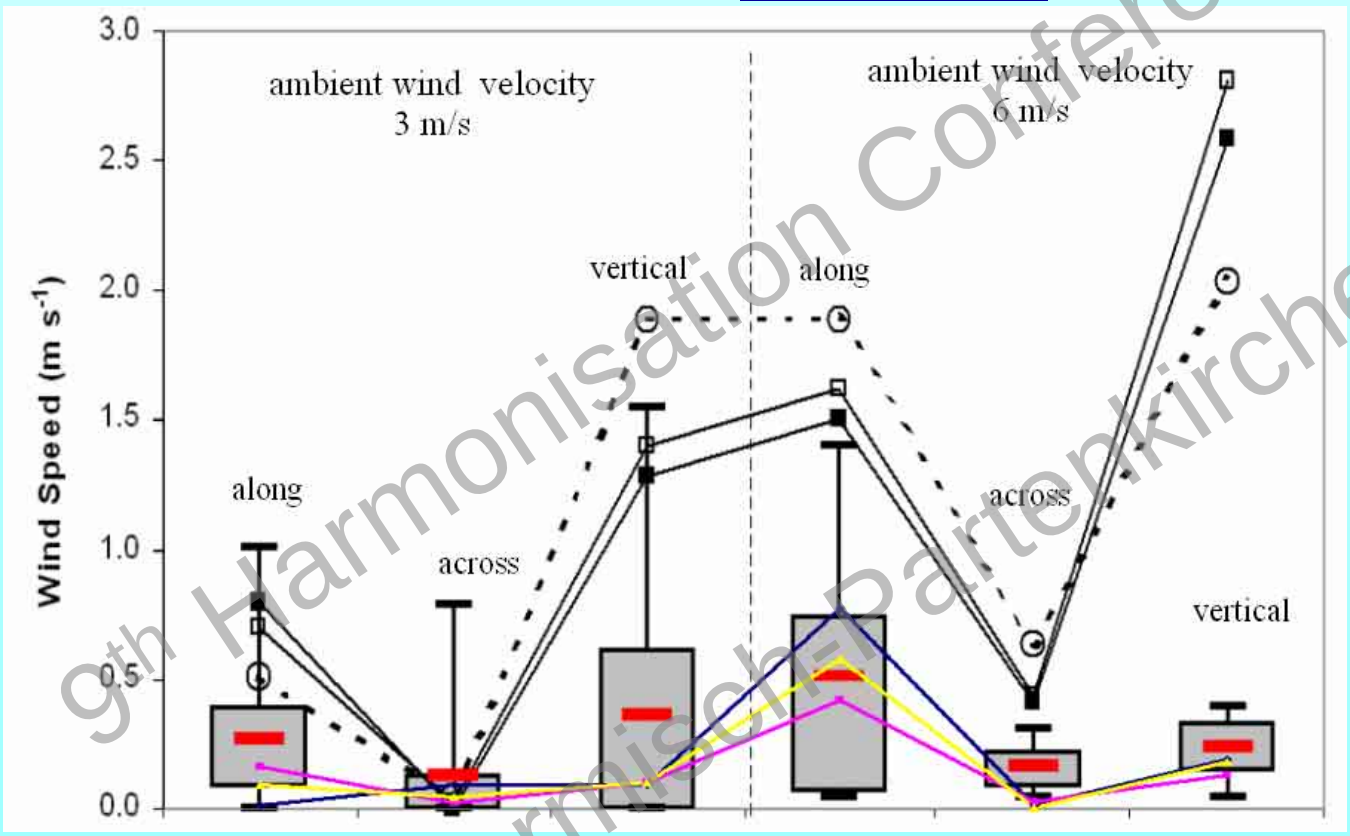
Comparison of results obtained from modeling and experiment for oblique flow

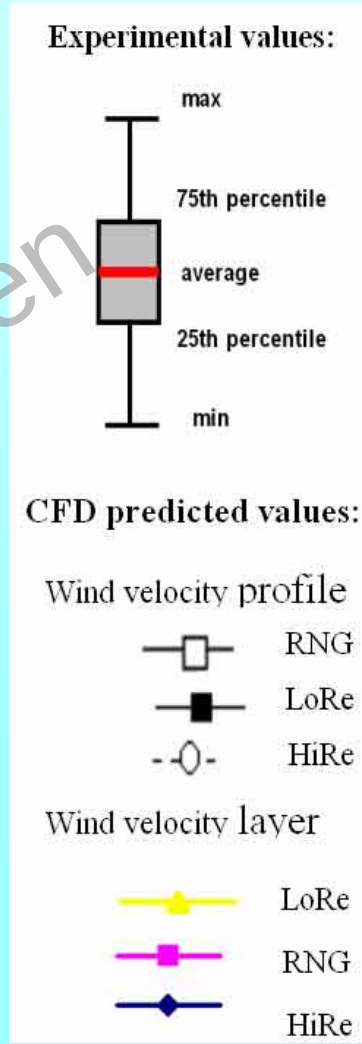




„Wind velocity profile" gives generally higher wind velocity values in comparison with "wind velocity layer" only for vertical component of wind velocity.

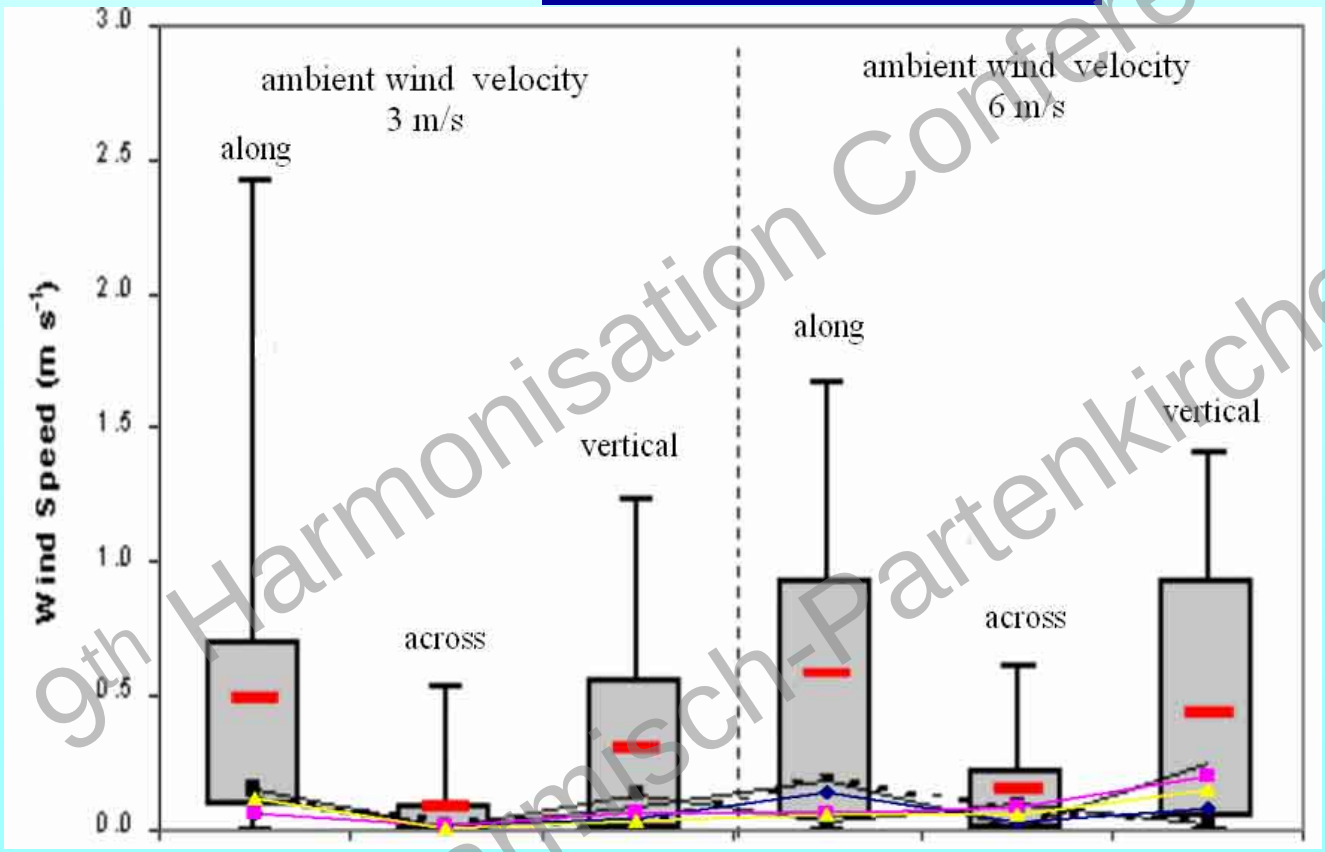
Comparison of results obtained from modeling and experiment for parallel flow

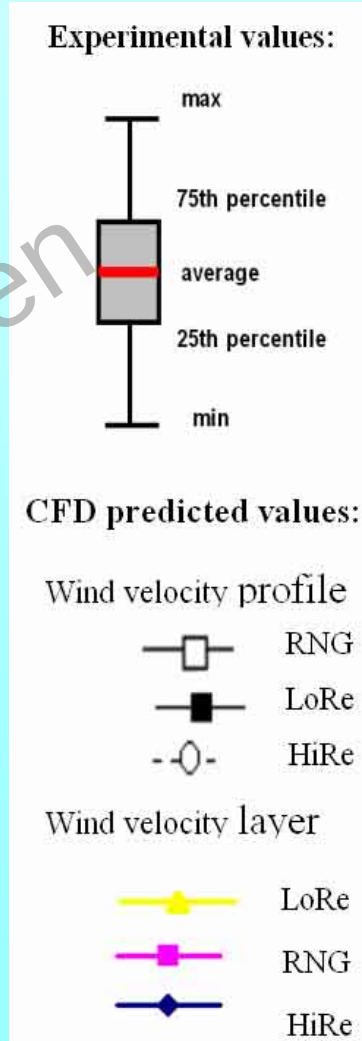




„Wind velocity profile" gives generally higher wind velocity values in comparison with "wind velocity layer"

Comparison of results obtained from modeling and experiment for perpendicular flow





Predictions obtained by both kinds of wind conditions underestimate wind velocity

CONCLUSIONS

The “wind velocity layer” corresponds with the average experimental values in case of parallel wind flow.

Predictions obtained by both kinds of wind conditions underestimate wind velocity in case of perpendicular wind direction.

K-ε RNG model of turbulence and “wind velocity layer” boundary condition configuration have provided the closest predicted values to measurement.