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MŰEGYETEM 1782

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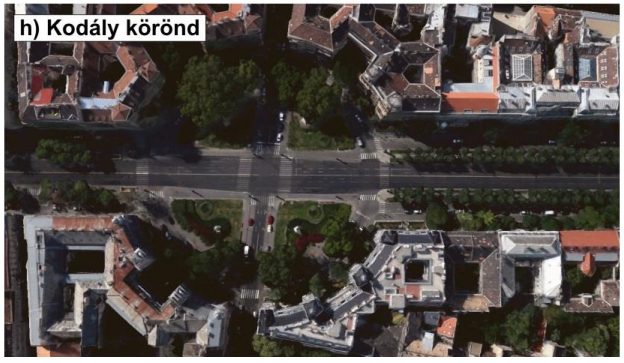
Theodore von Kármán Wind Tunnel Laboratory

Investigation of ventilation and air quality in urban squares

SHAPE OF URBAN SQUARES – BUDAPEST



- About 50 squares can be found in central Budapest
- Tens of thousands of inhabitants and much more pedestrians, guests etc use them.

SQUARE GEOMETRIES INVESTIGATED

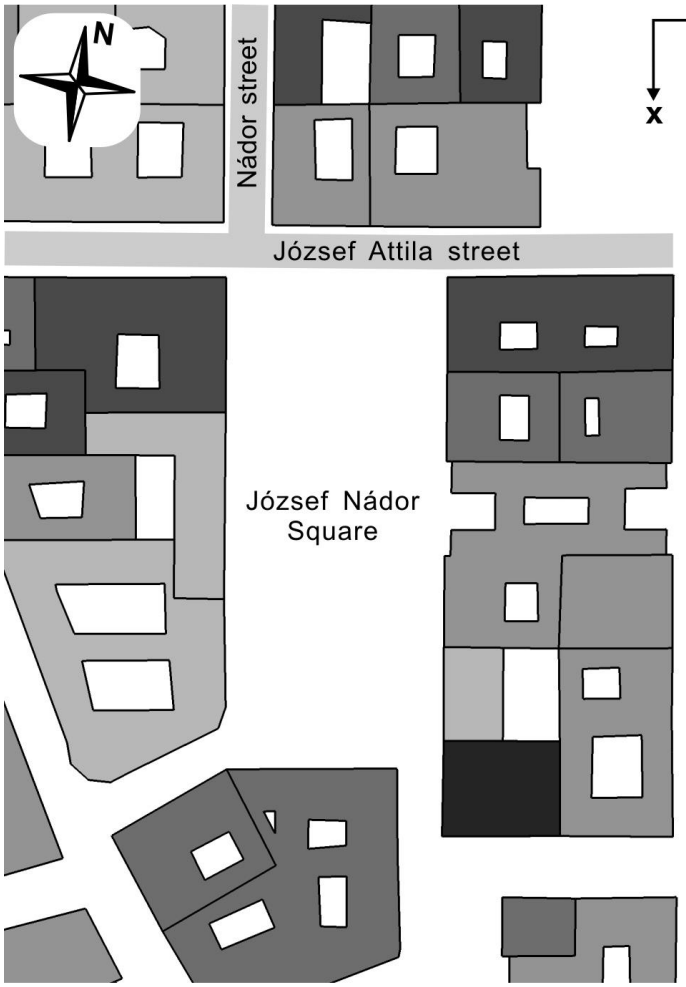
SQUARE

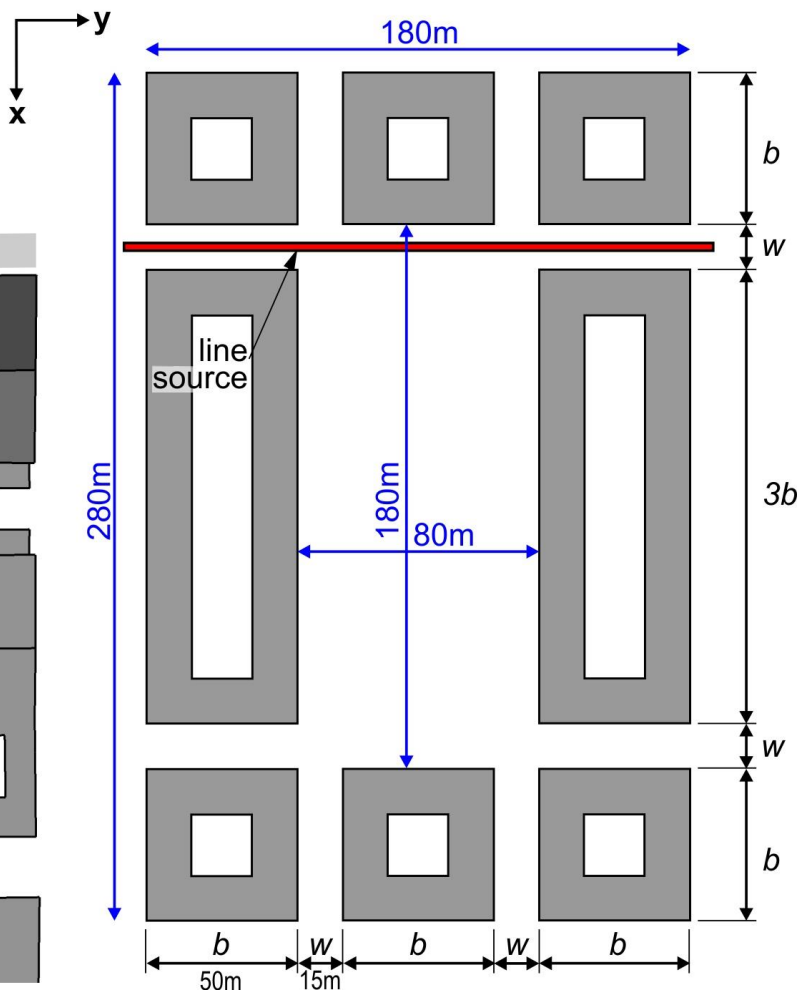
L / W = **2.25**

W / H = **6** (North)
= **2.67** (West)

STREETS

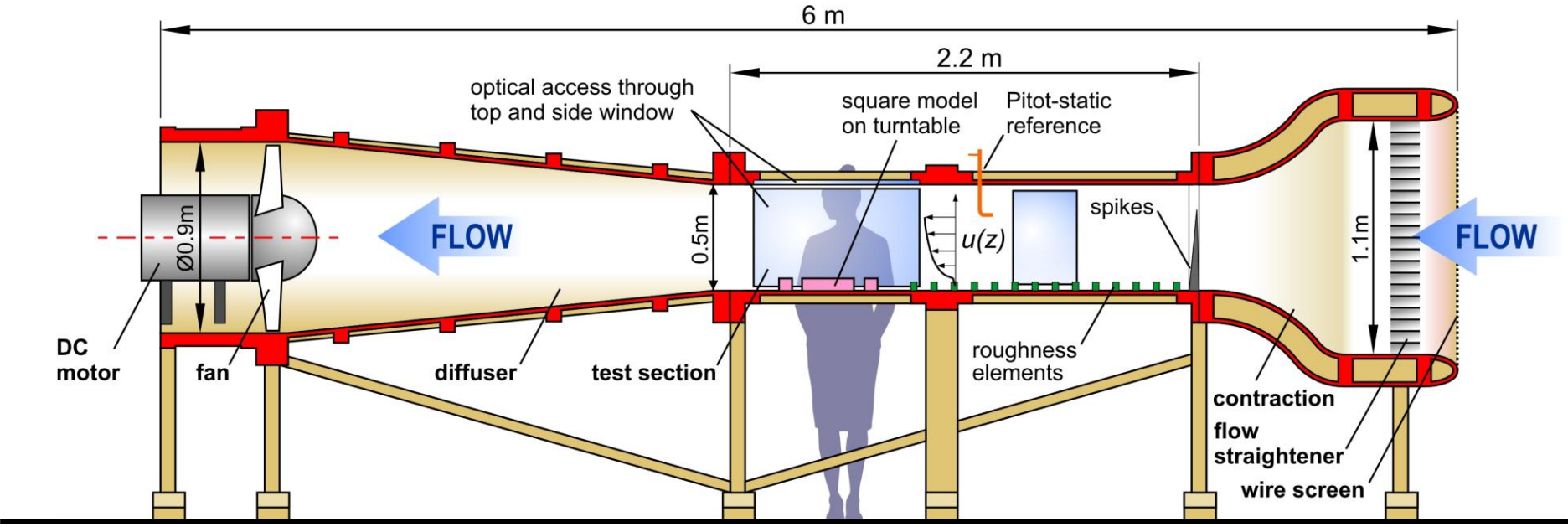
H / W = **2**



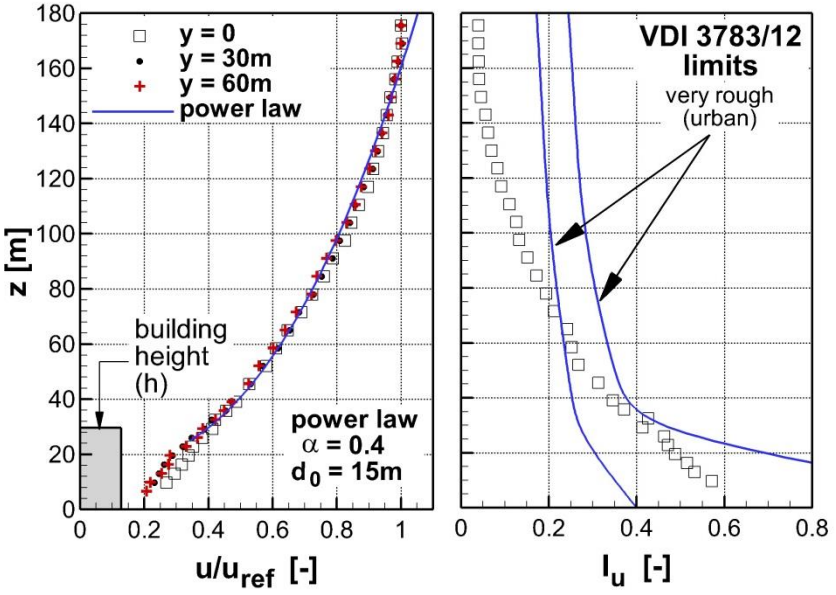


Building height H: 28 m (average) 30 m

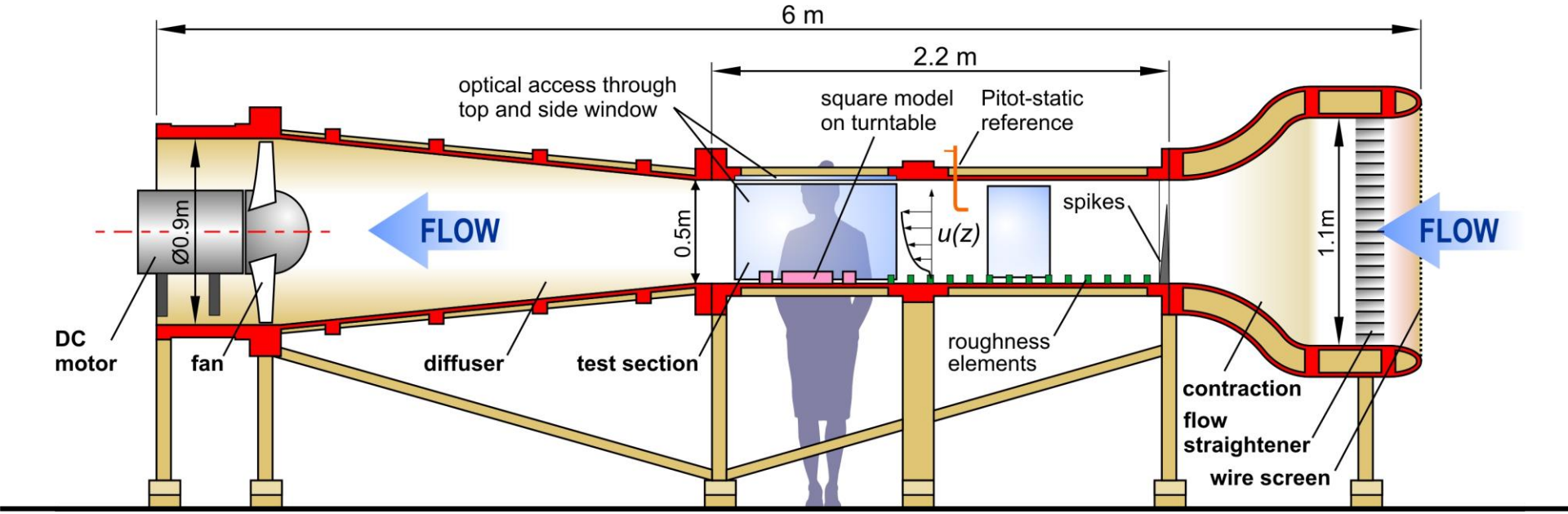
WIND TUNNEL TEST – SIMPLIFIED GEOMETRY

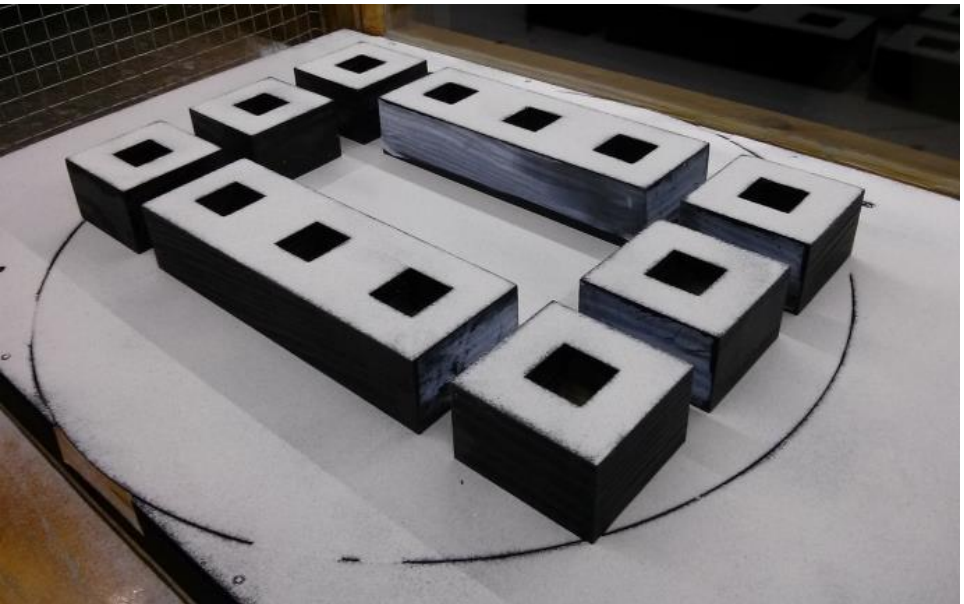


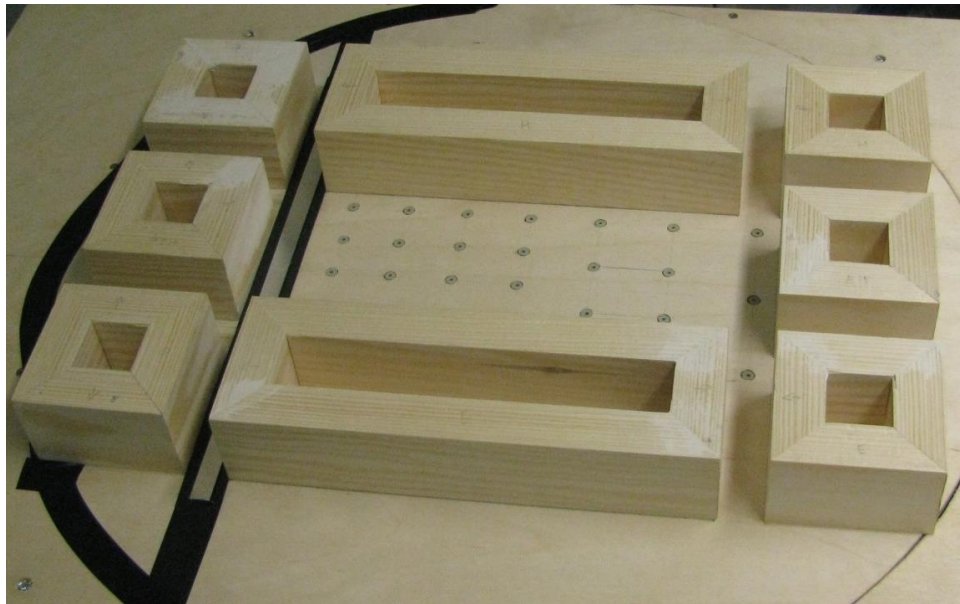
- Modelling of the atmospheric boundary layer
- 1:650 scale
- 5 wind directions
- Sand erosion test to estimate mean wind speed v_{md}
- Dispersion test from a line source, concentration measurement in 41 points



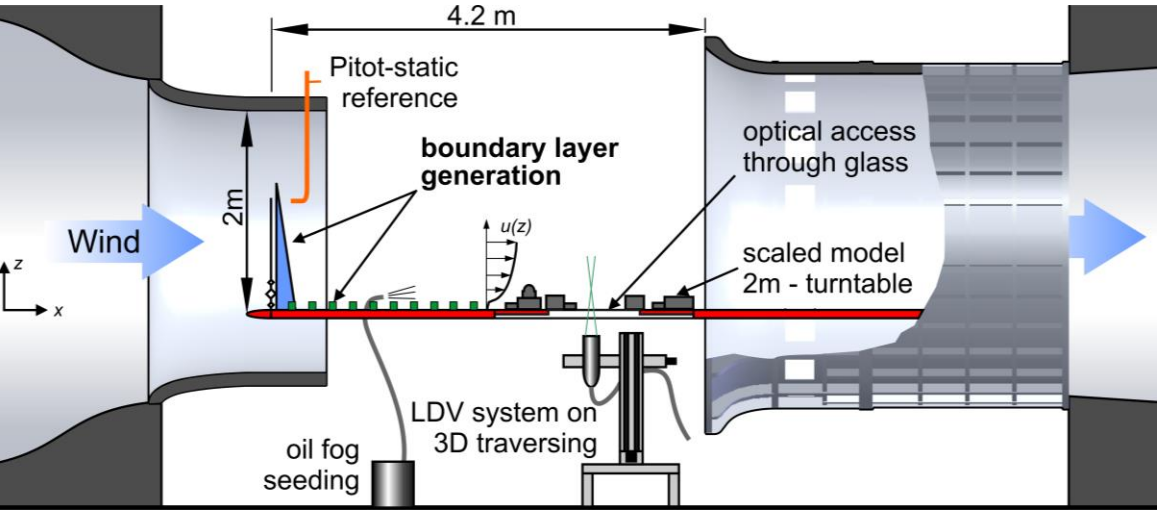
WIND TUNNEL TEST – SIMPLIFIED GEOMETRY



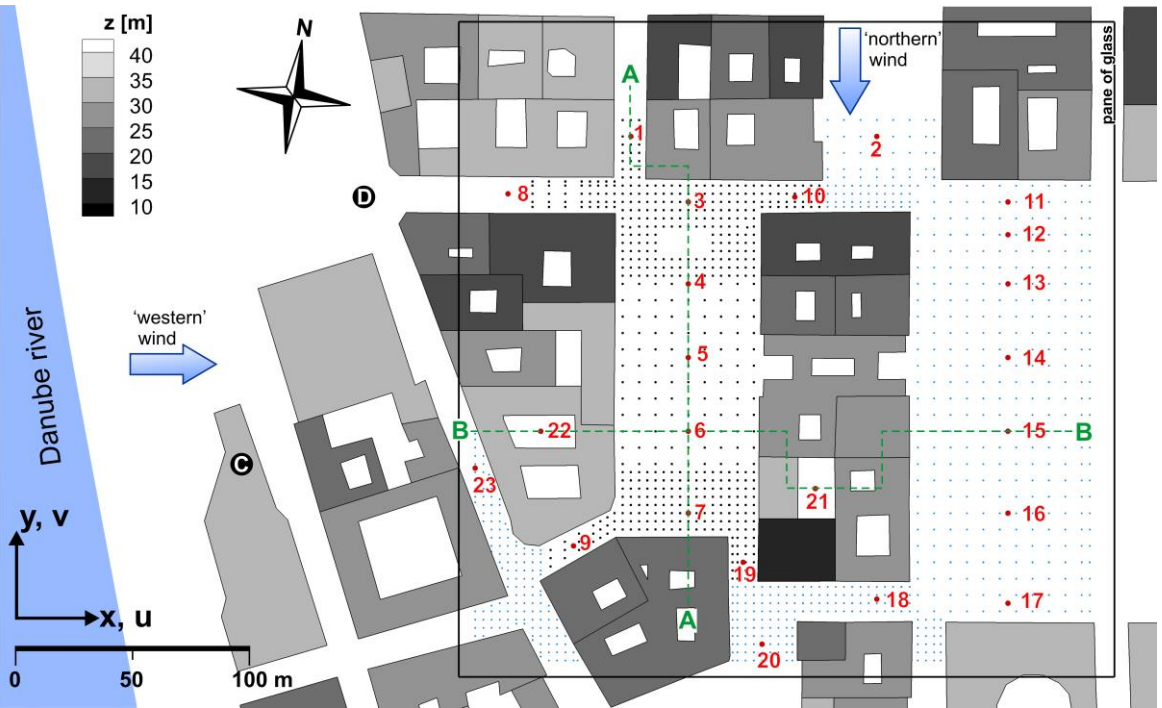


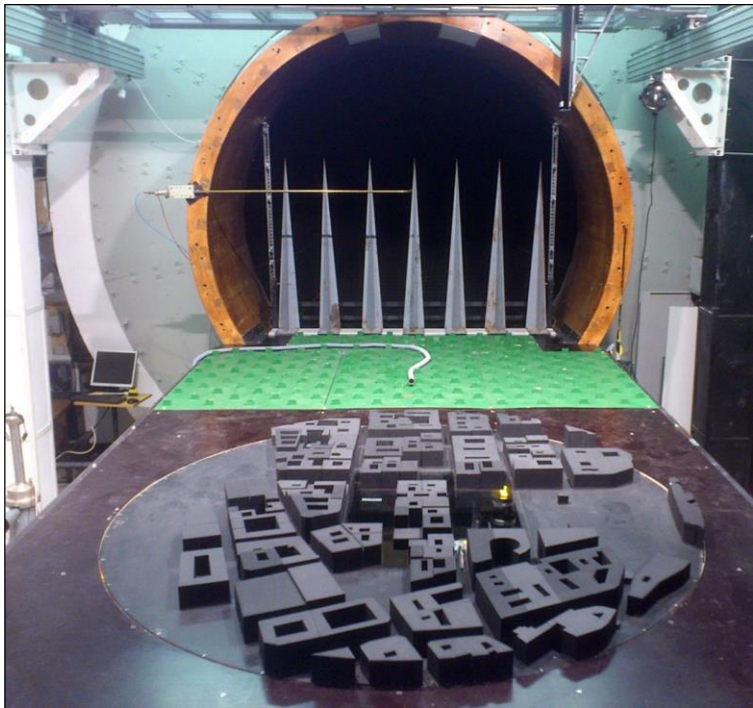


WIND TUNNEL TEST – REAL GEOMETRY



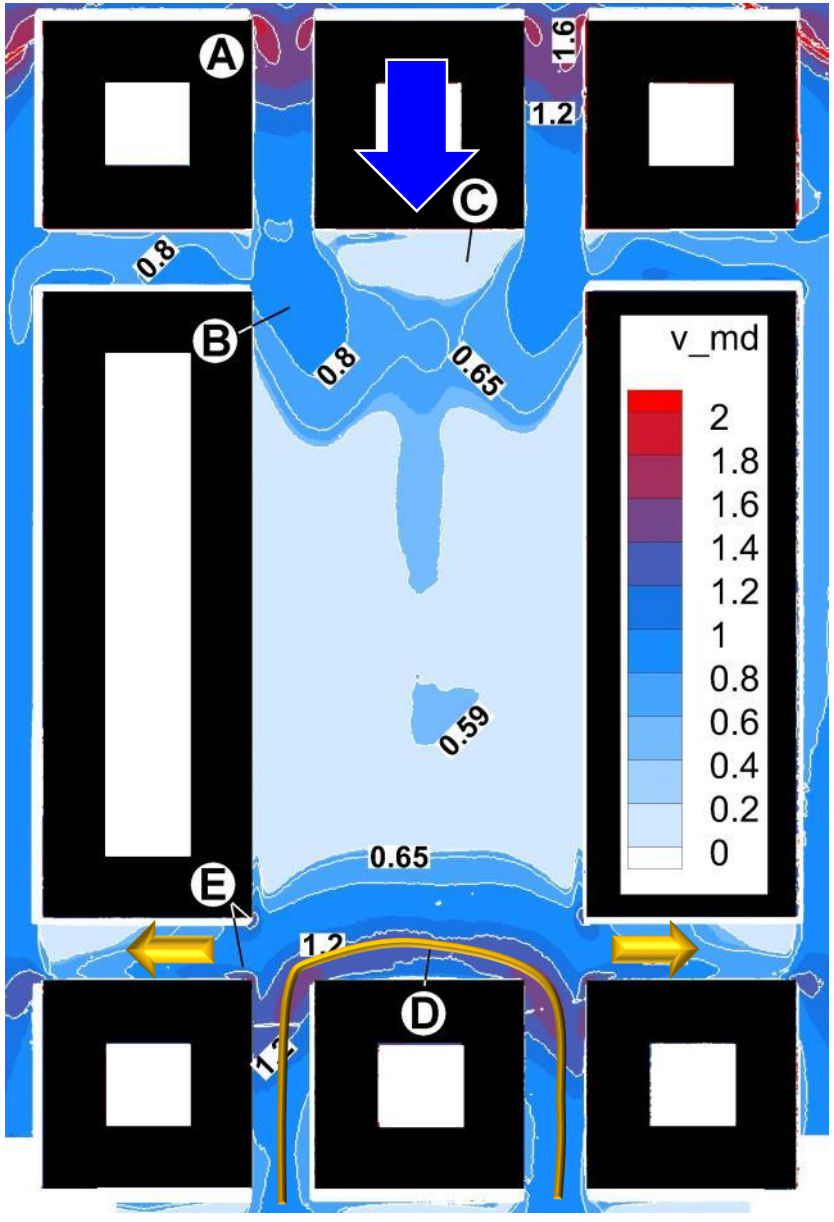
- 1:350 scale
- LDA measurement for the **u** and **v** horizontal flow components (from below)
- 2 wind directions, ~5500 points
- Flat roofs, categorized building heights

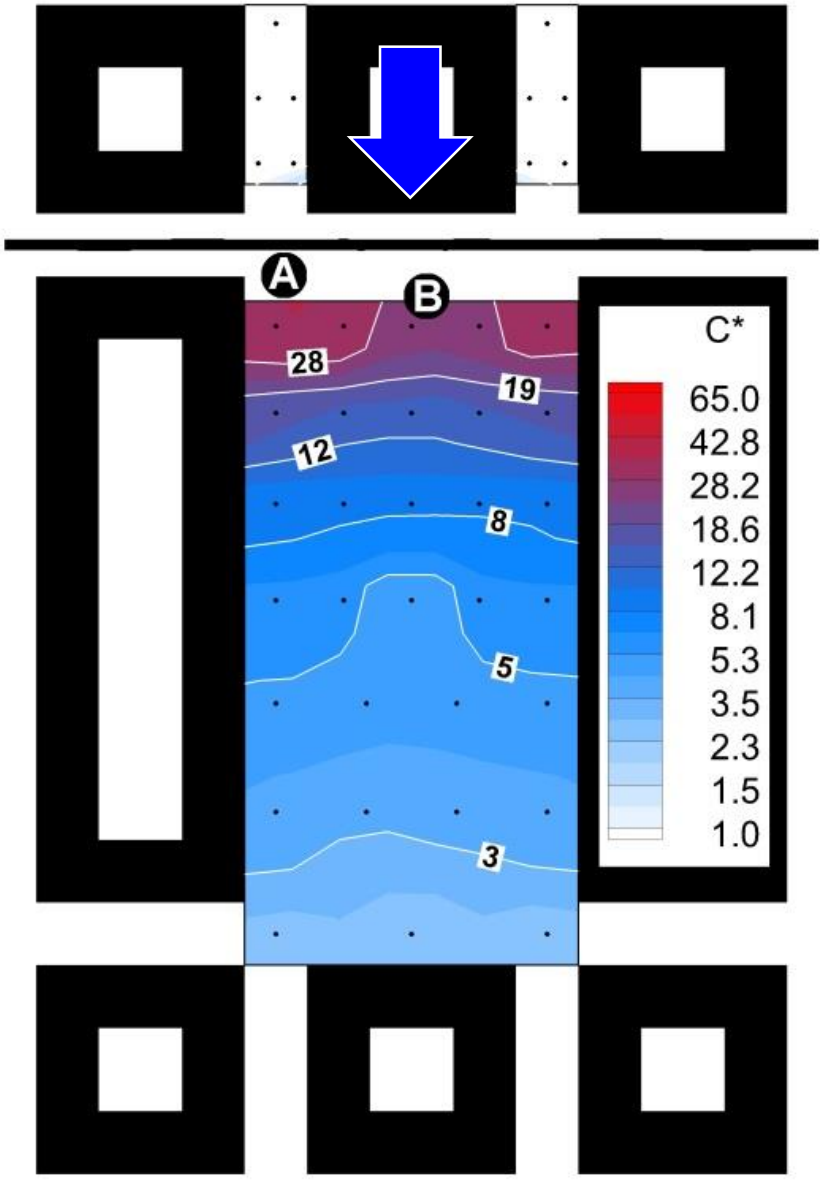




WIND FROM NORTH
MEAN WIND SPEED & CONCENTRATION

WIND TUNNEL (SAND EROSION)



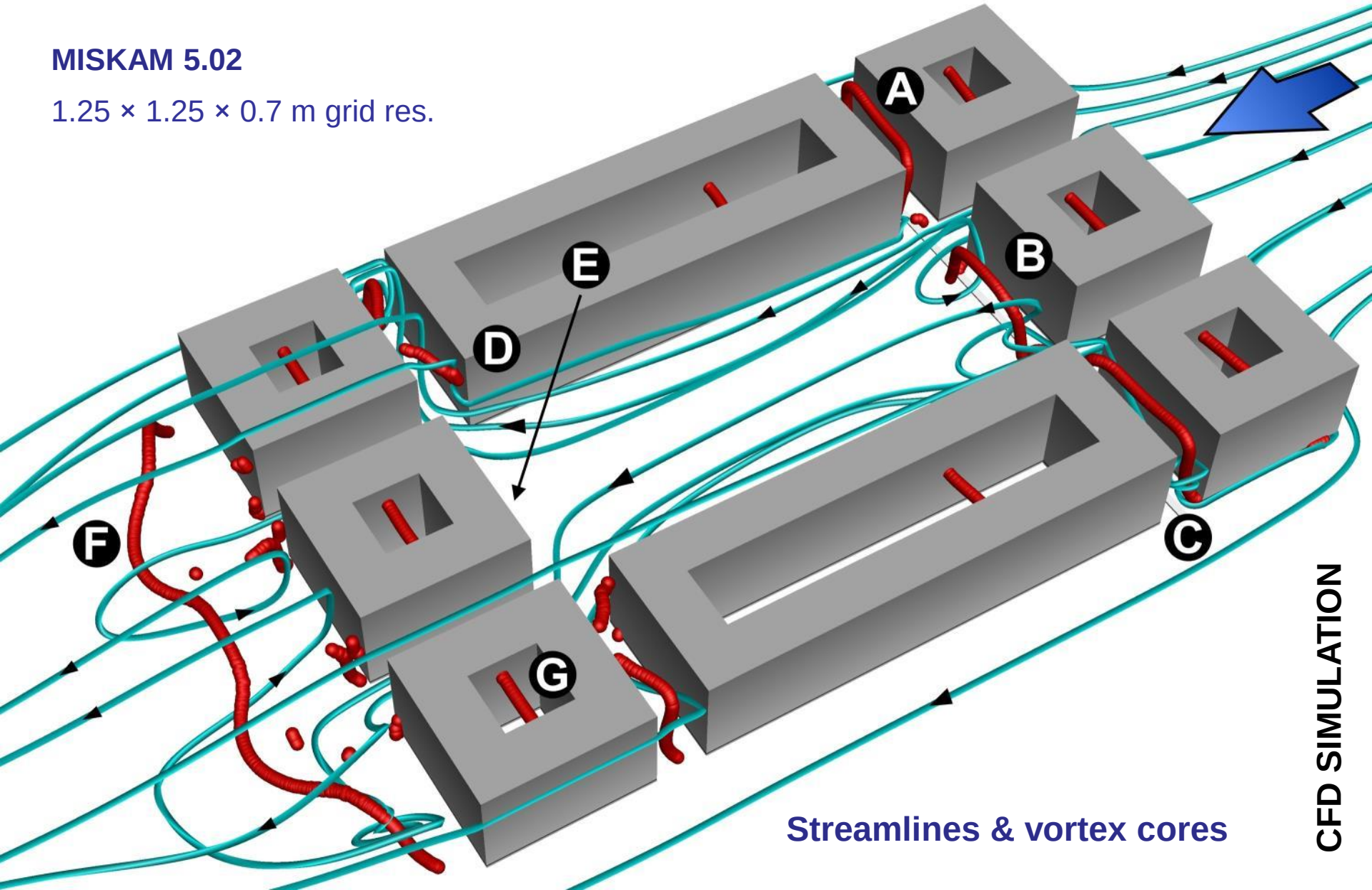


WIND TUNNEL (TRACER DISPERSION)

WIND FROM NORTH – FLOW STRUCTURES

MISKAM 5.02

1.25 × 1.25 × 0.7 m grid res.

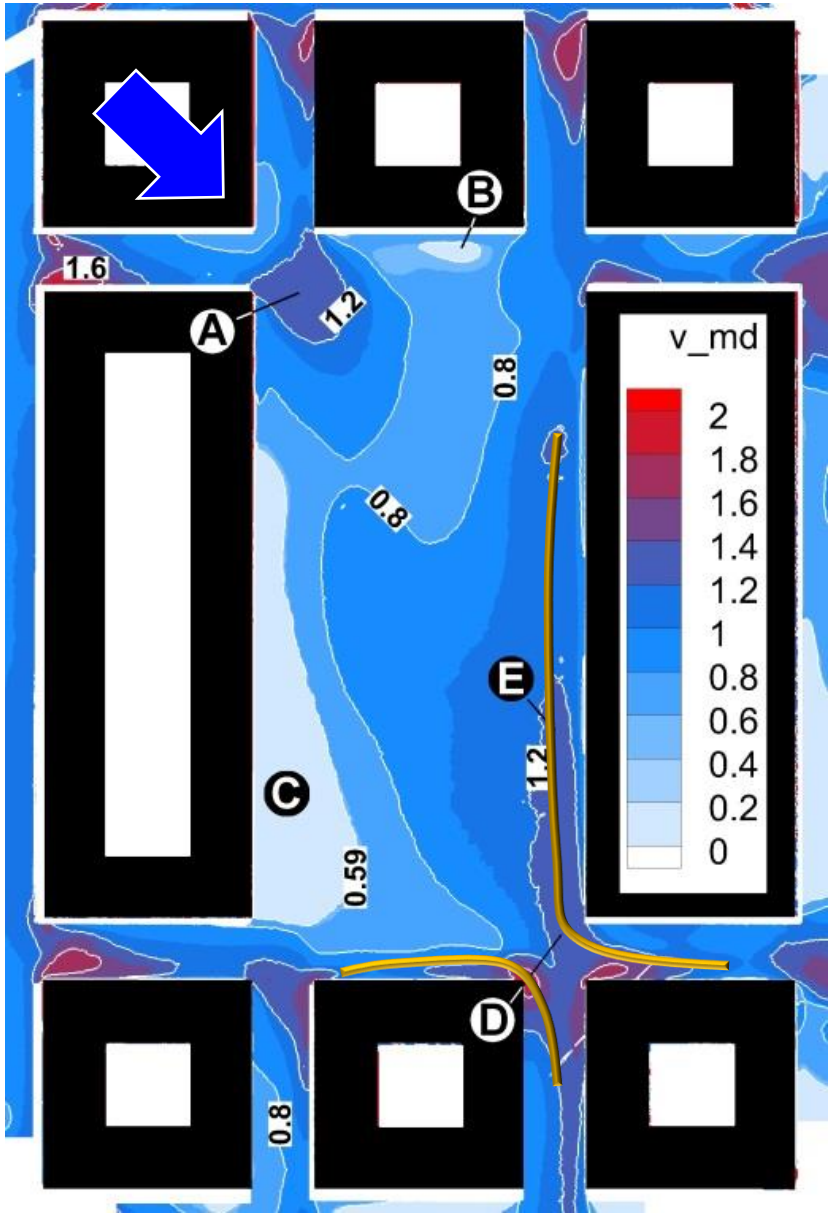


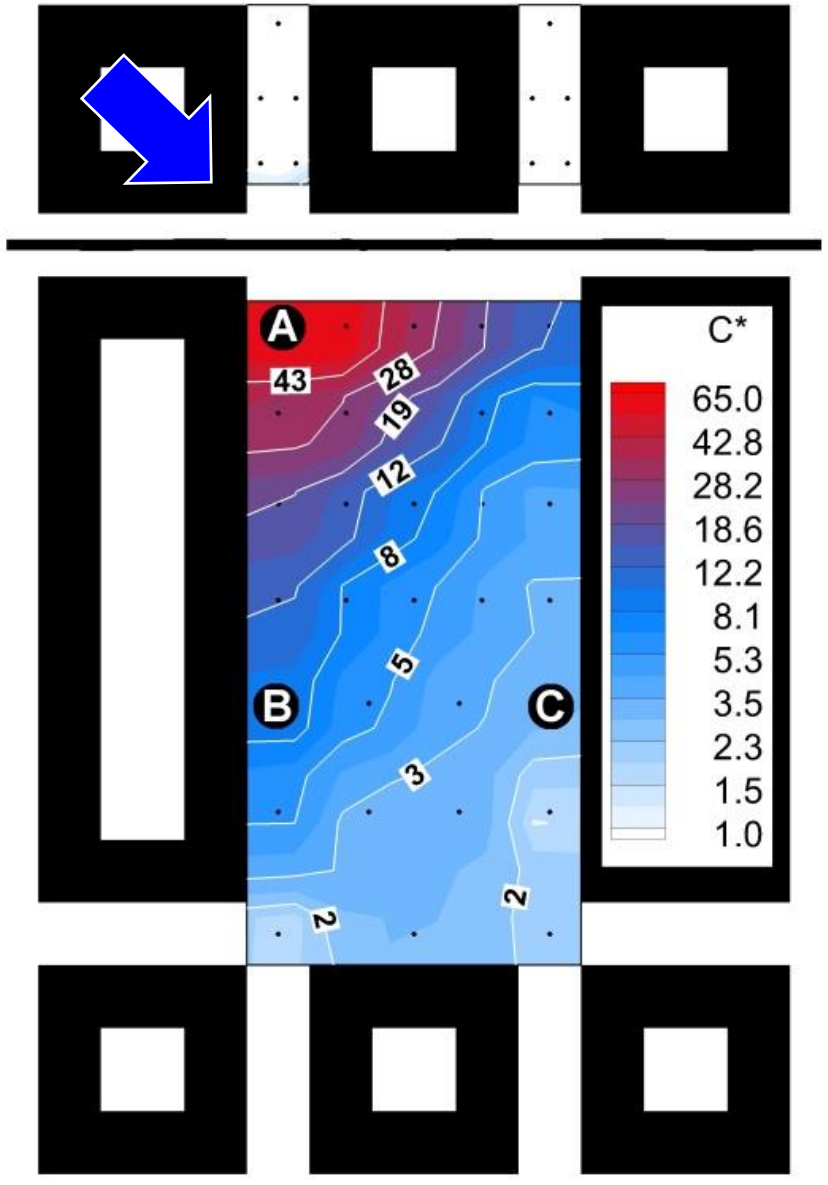
Streamlines & vortex cores

CFD SIMULATION

WIND FROM NORTHWEST
MEAN WIND SPEED & CONCENTRATION

WIND TUNNEL (SAND EROSION)

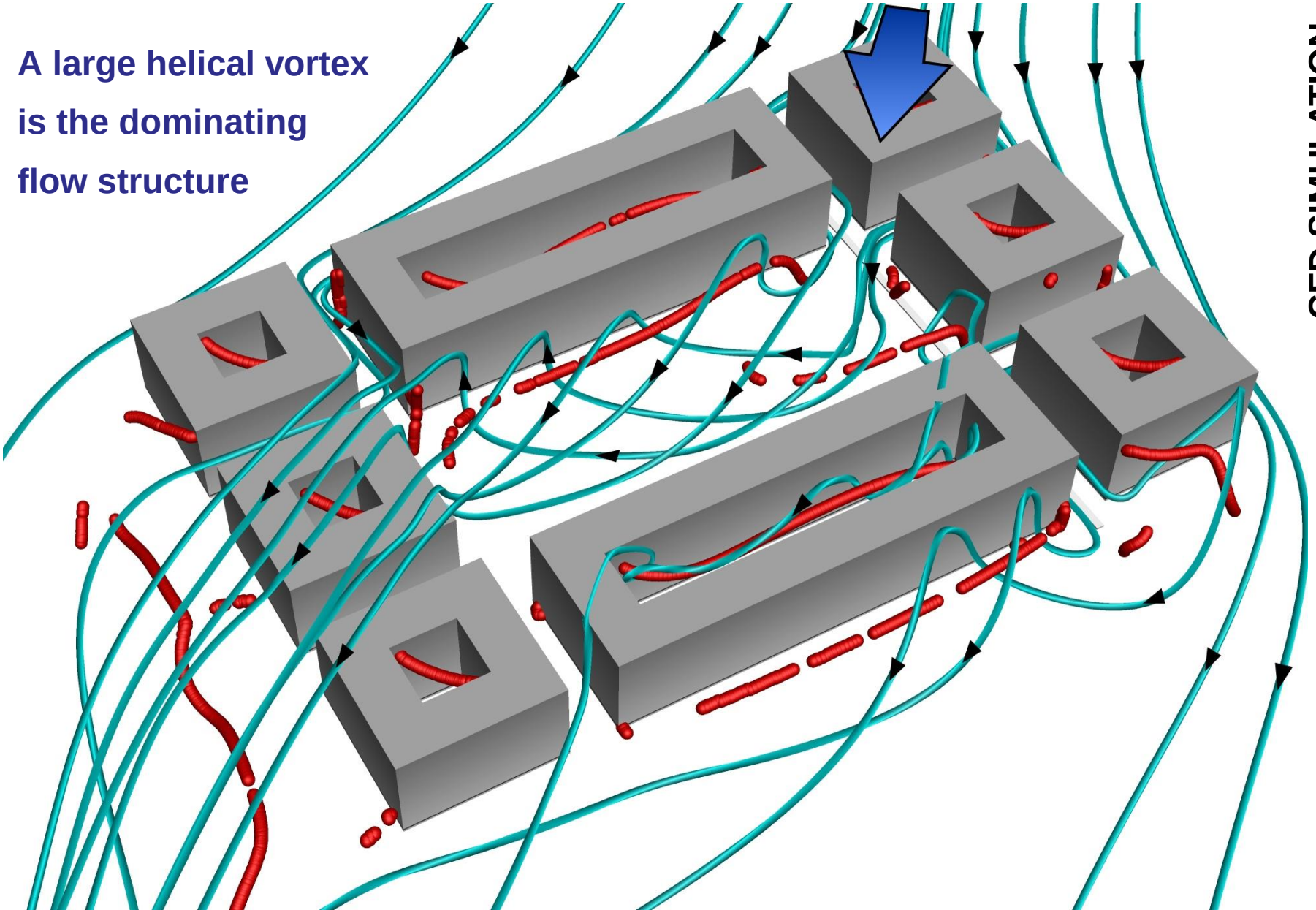




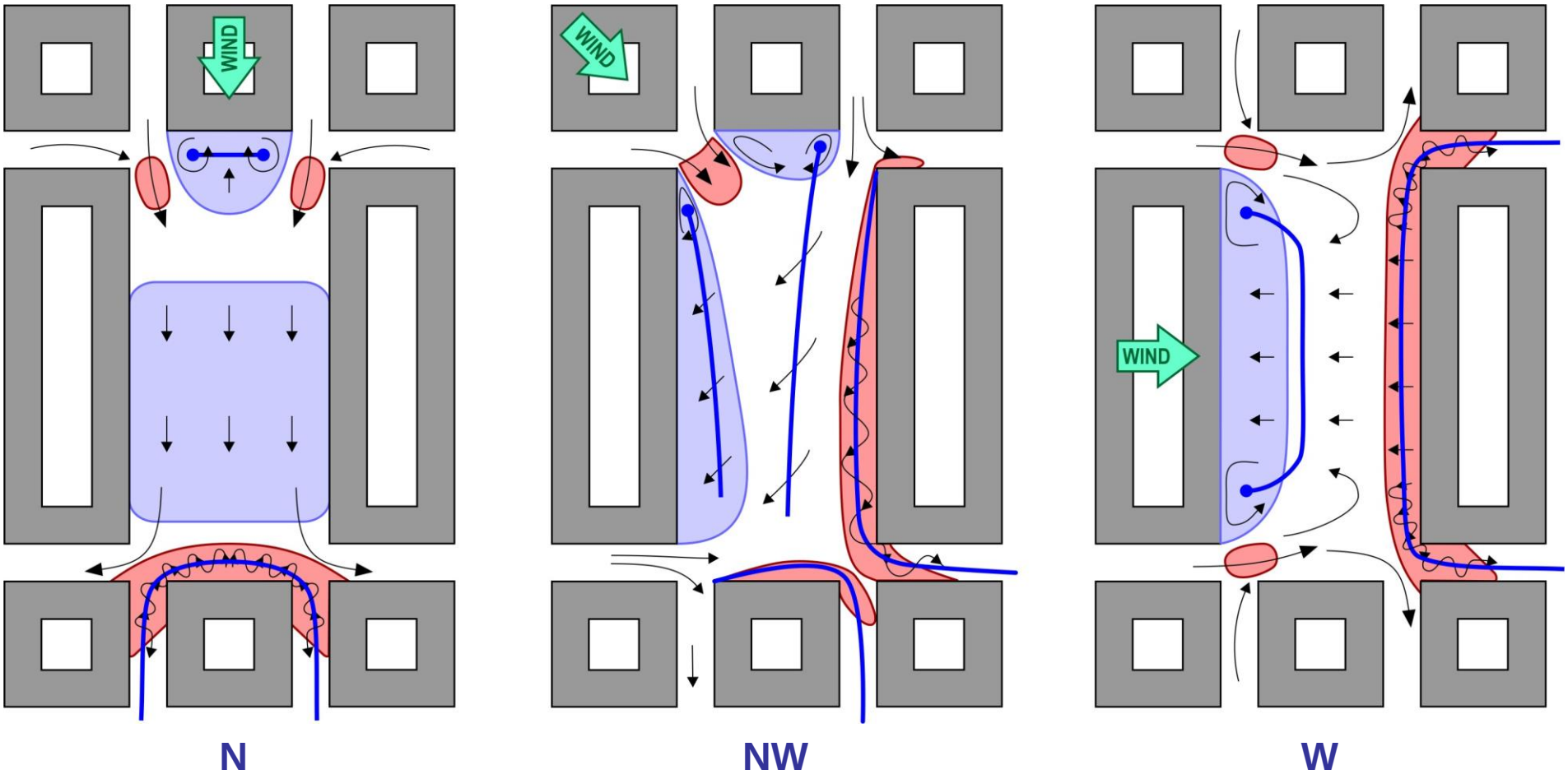
WIND TUNNEL (TRACER DISPERSION)

WIND FROM NORTHWEST – FLOW STRUCTURES

A large helical vortex is the dominating flow structure

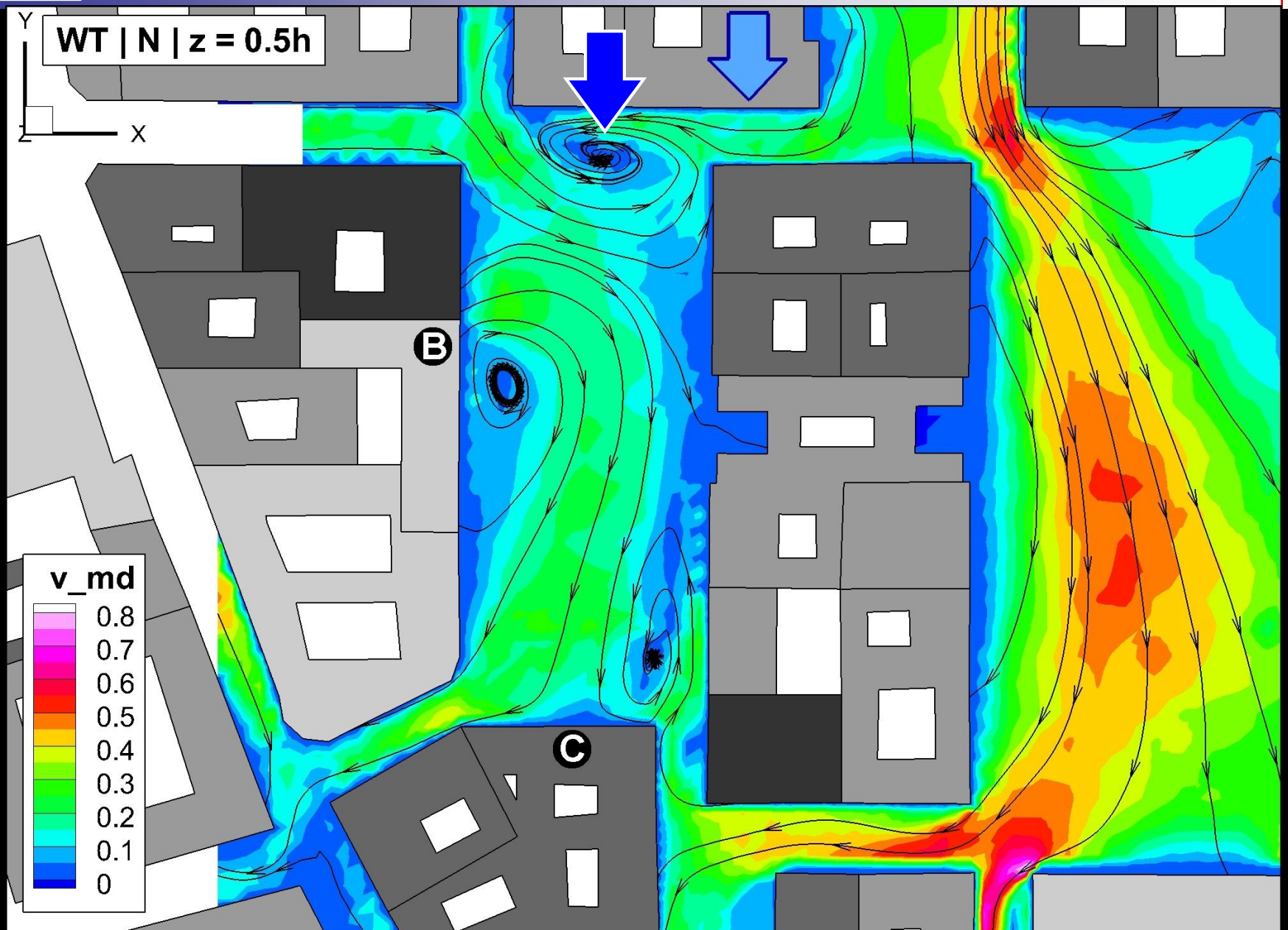


FLOW SCHEMATICS RECONSTRUCTED FROM SAND EROSION AND CFD RESULTS

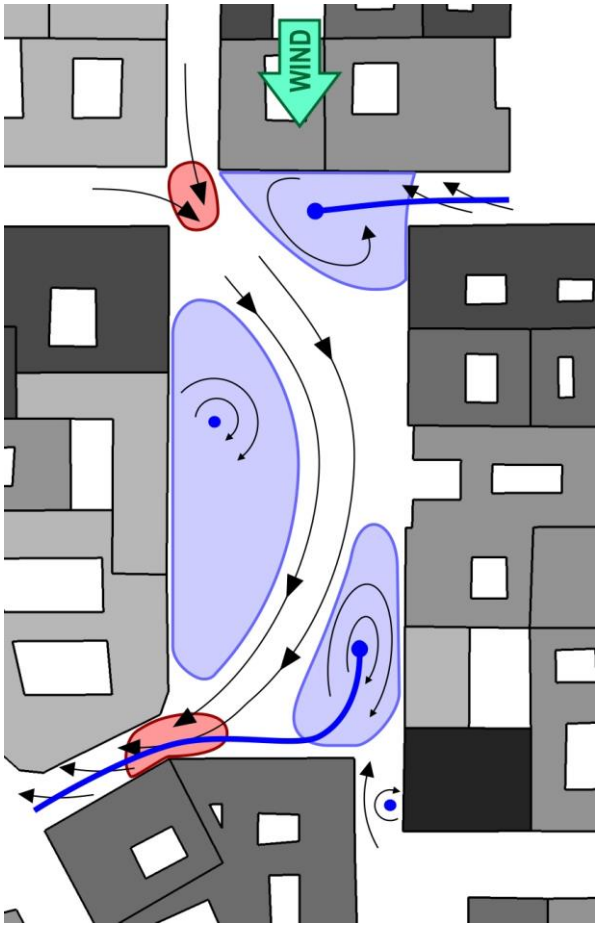


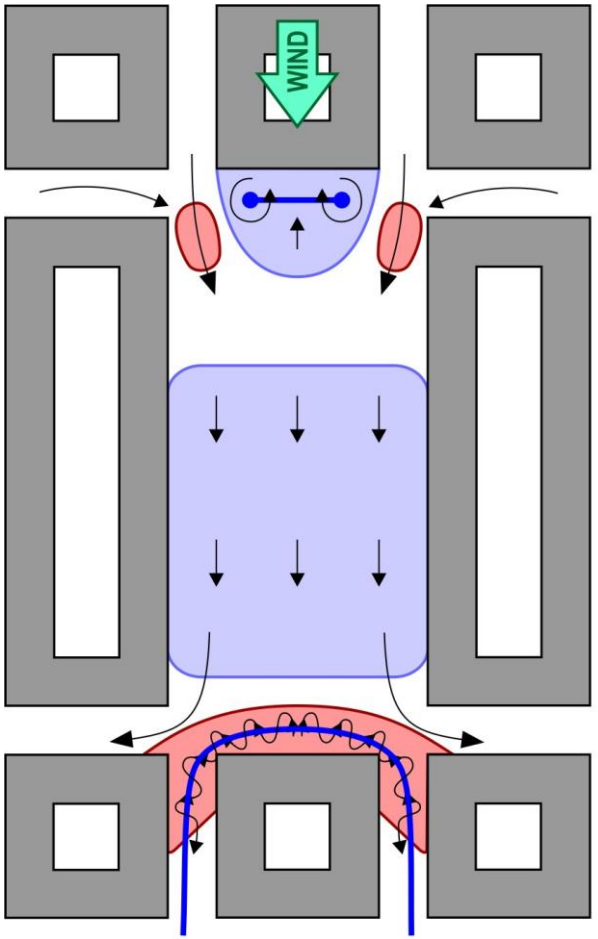
REAL GEOMETRY – WIND FROM THE NORTH
MEAN WIND SPEED AT Z = 0.5 H

WIND TUNNEL (LDV)



FLOW SCHEMATICS RECONSTRUCTED FROM LDV MEASUREMENTS





Low ground-level speed

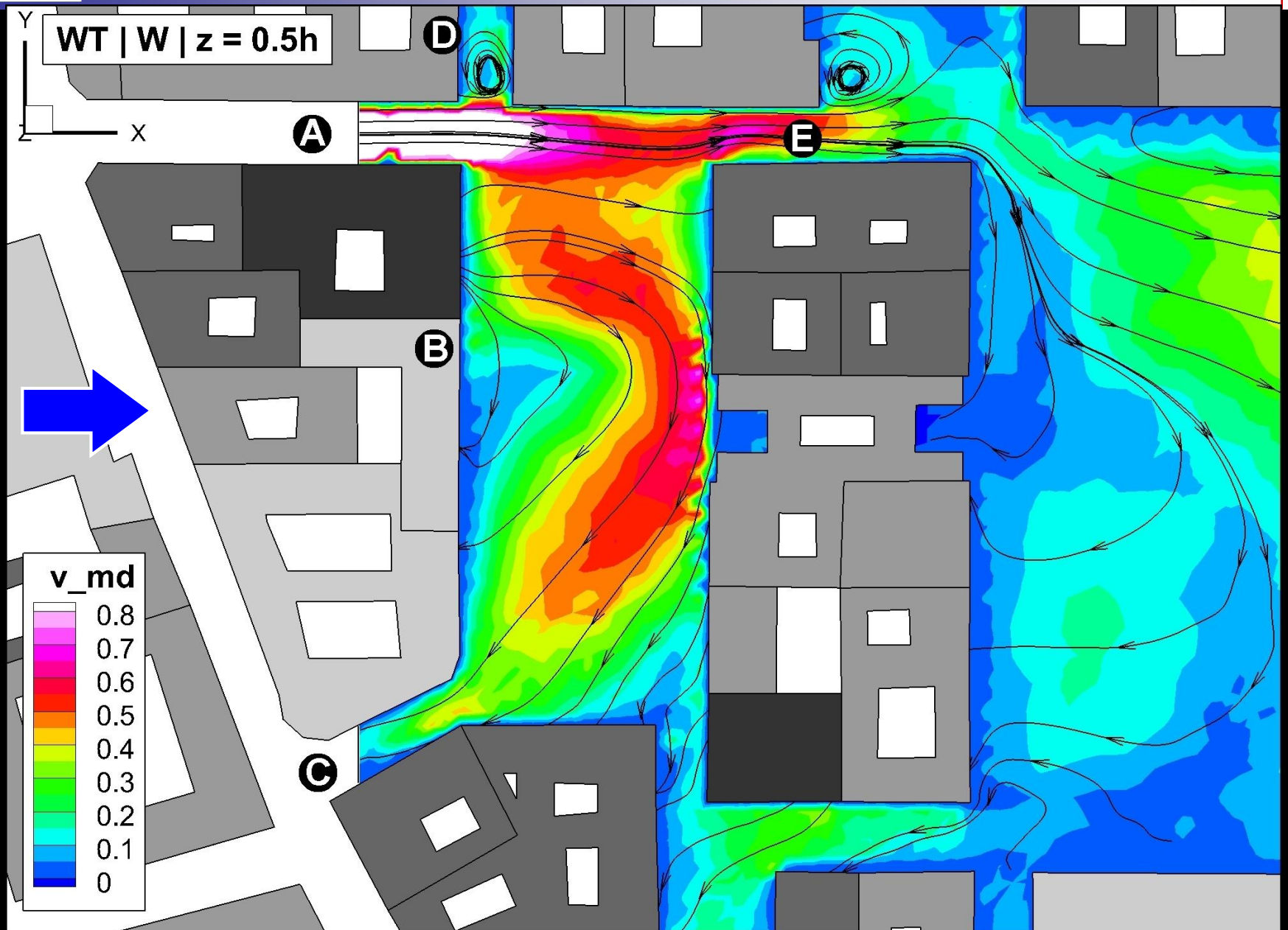
High ground-level speed

Ground-level wind direction

Vortex core (starting from the surface)

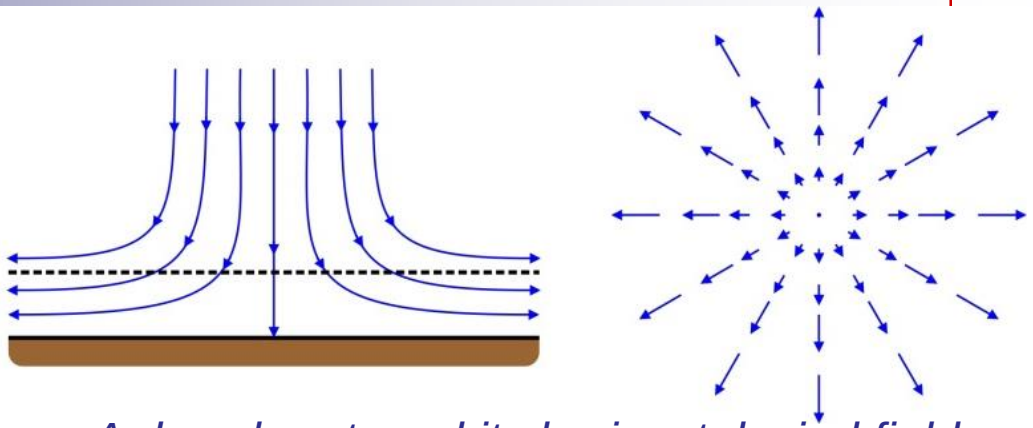
REAL GEOMETRY – WIND FROM THE WEST
MEAN WIND SPEED AT Z = 0.5 H

WIND TUNNEL (LDV)



SIMPLE METHOD TO ESTIMATE THE VERTICAL VELOCITY COMPONENT

Close the ground, divergence of horizontal wind components shows the existence of down- or updrafts.



A downburst and its horizontal wind field

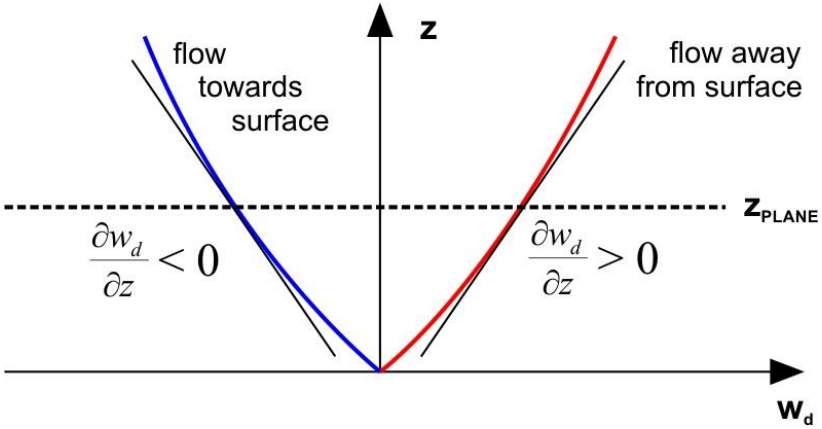
Continuity equation

$$\frac{\partial u_d}{\partial x} + \frac{\partial v_d}{\partial y} + \frac{\partial w_d}{\partial z} = div\left(\underline{v}_d\right) = 0$$

Calculation of vertical flow gradient

$$-\frac{\partial w_d}{\partial z} = \left(\frac{\partial u_d}{\partial x} + \frac{\partial v_d}{\partial y}\right) = div\left(\underline{v}_{hor\,d}\right)$$

Assumption near the ground: gradient proportional to vertical wind component

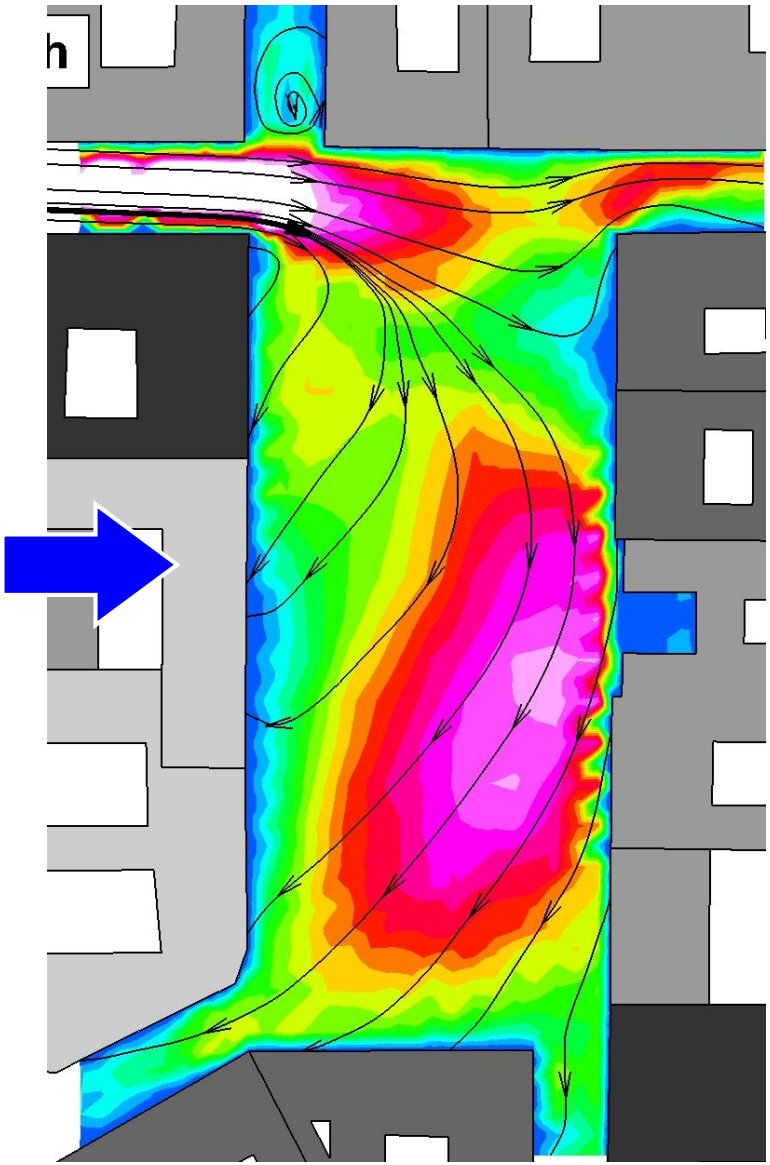


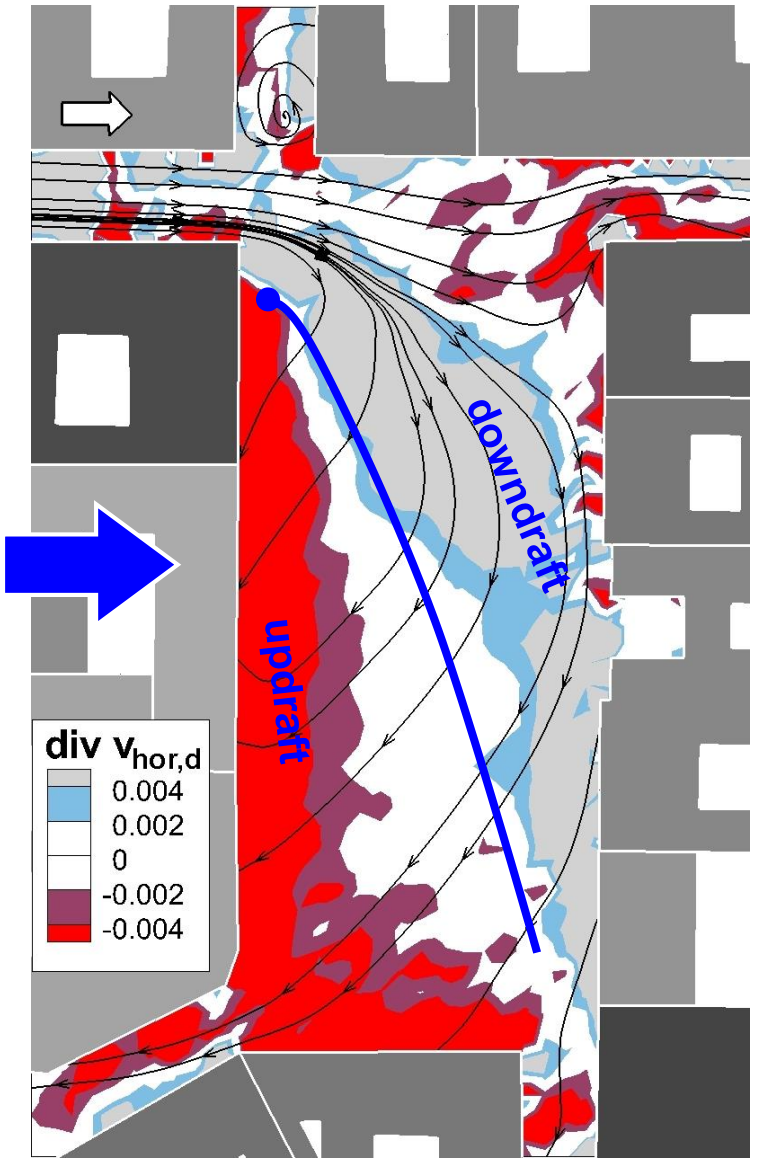
$$\frac{\partial w_d}{\partial z} \approx \frac{w_d}{z_{plane}}$$

$$\Rightarrow w_d = -div\left(\underline{v}_{hor\,d}\right) \cdot z_{plane}$$

SIMPLE METHOD TO ESTIMATE THE VERTICAL VELOCITY COMPONENT

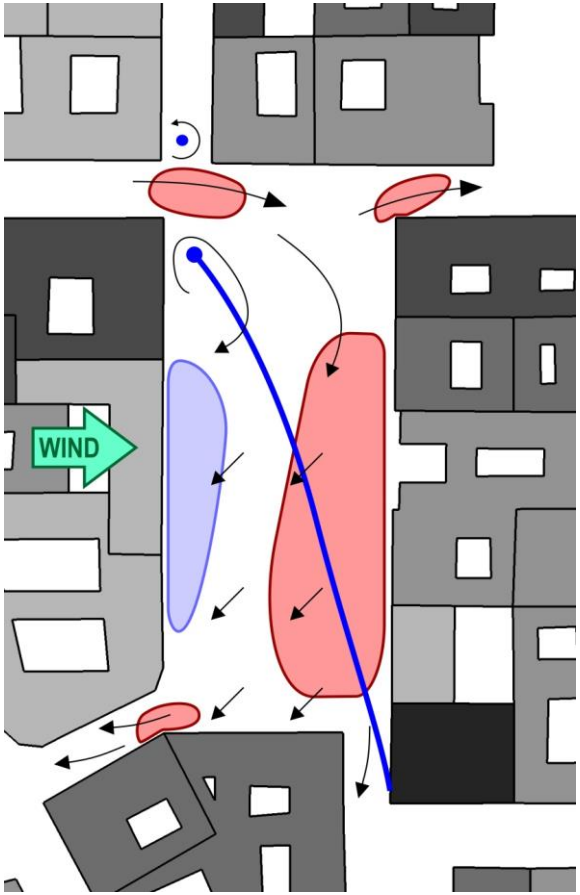
WIND TUNNEL (LDV)

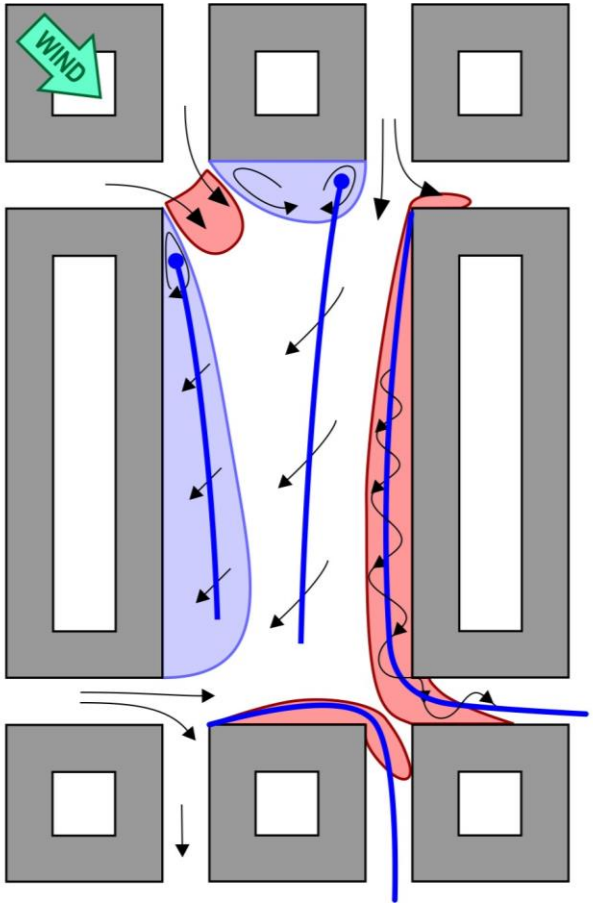




VERTICAL COMPONENT CALCULATED FROM WIND TUNNEL (LDV) RESULTS

FLOW SCHEMATICS RECONSTRUCTED FROM LDV MEASUREMENTS





Low ground-level speed

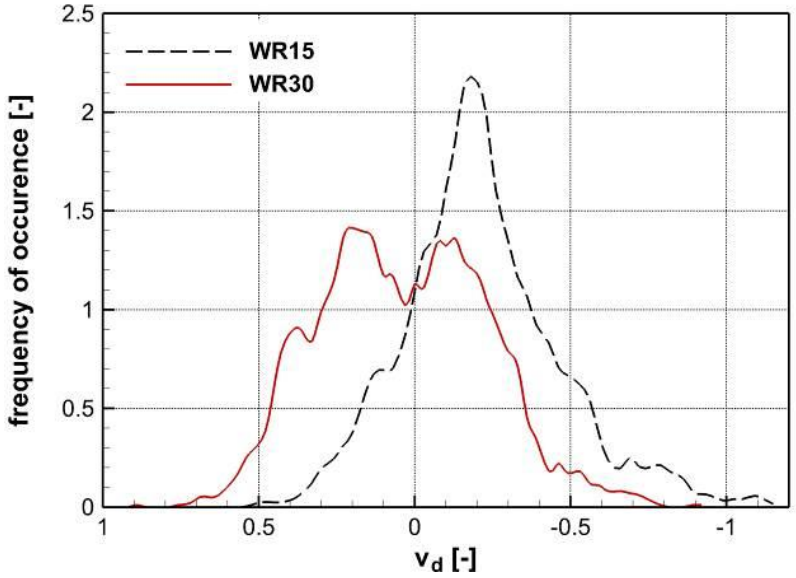
High ground-level speed

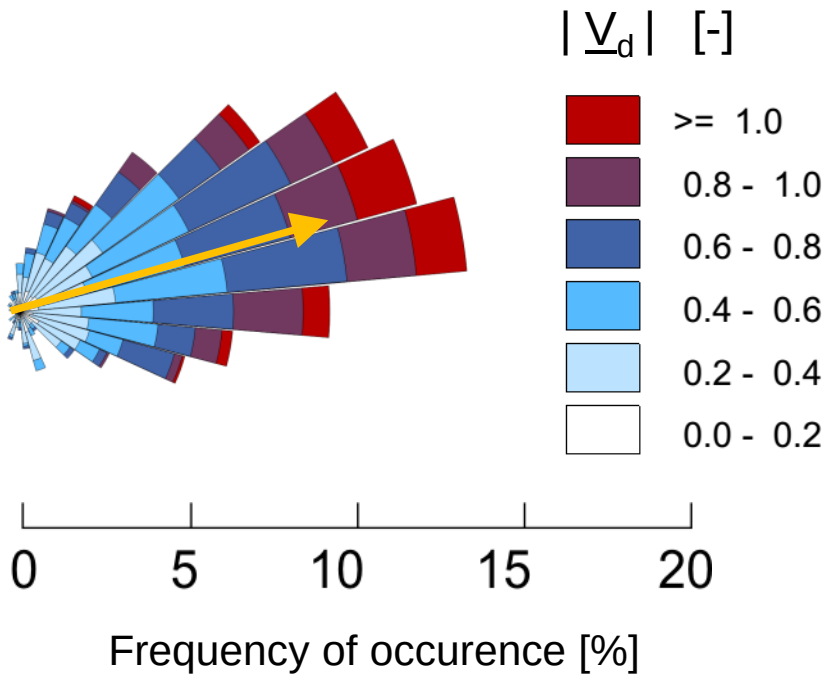
Ground-level wind direction

Vortex core (starting from the surface)

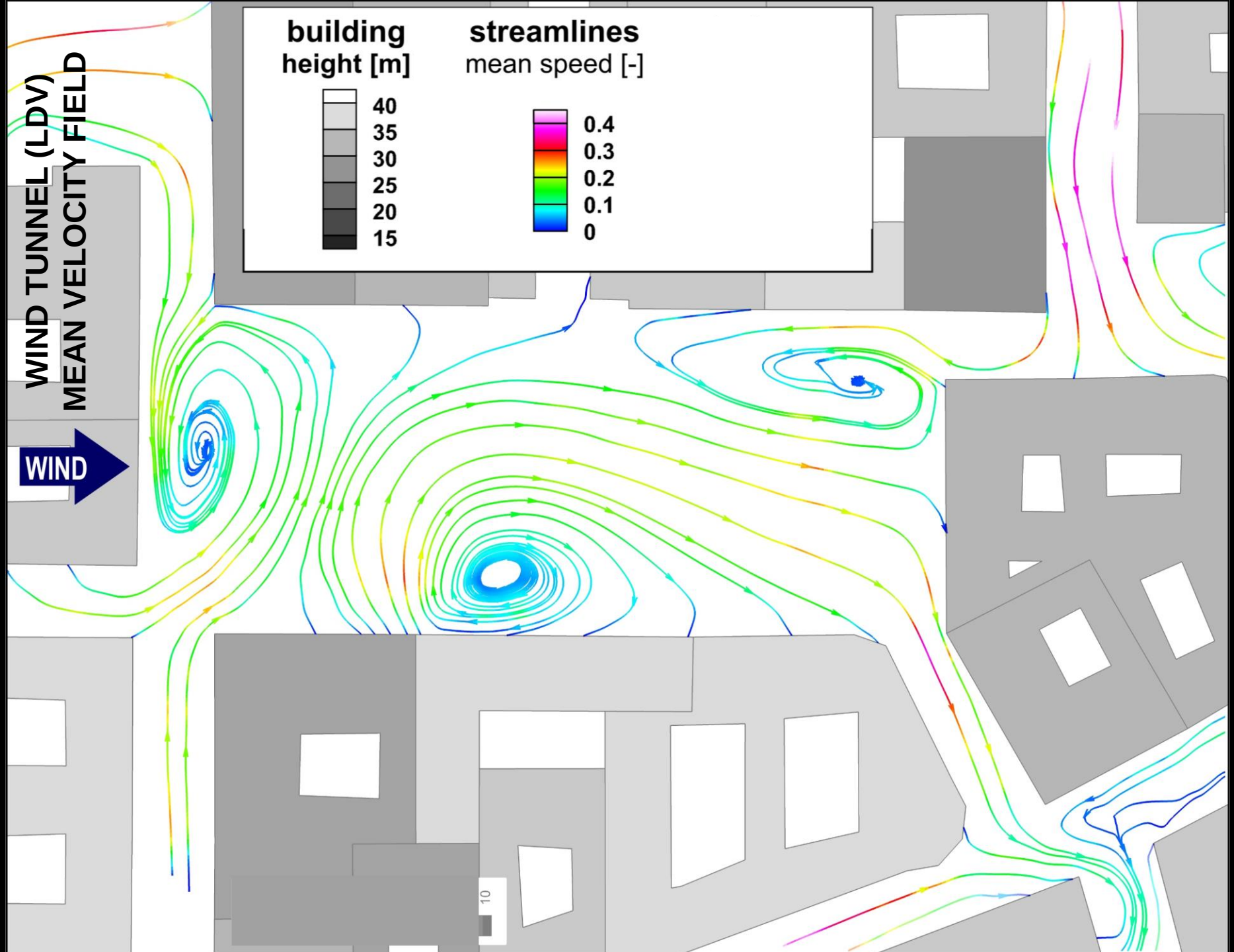
ANALYSIS OF UNSTEADY FLOW USING WIND ROSES

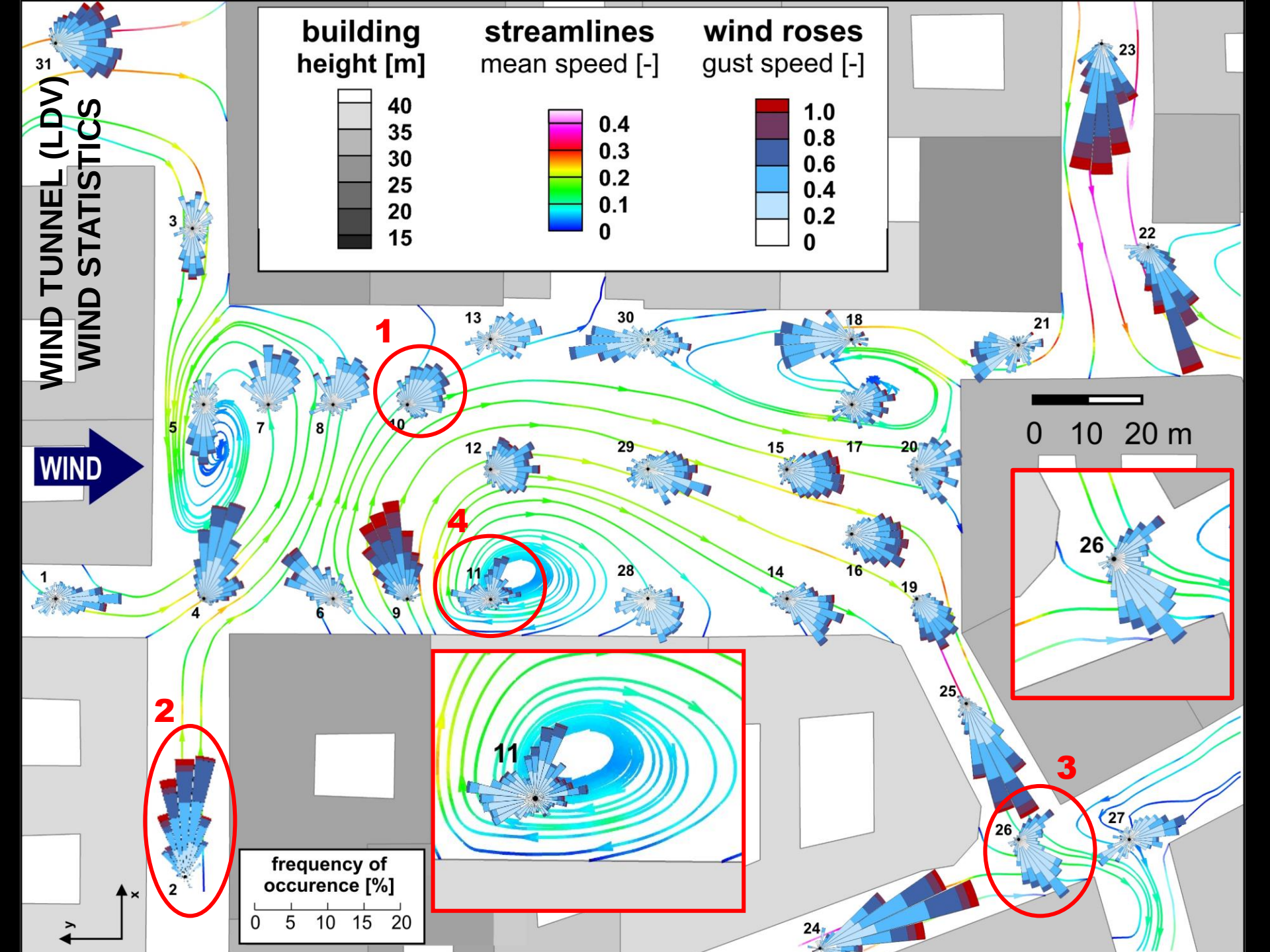
- LDV measurements: simultaneous **u** and **v** data
- Component histograms and higher order moments
- Use of wind roses to see flow (an)isotropy and eventually, flow switching





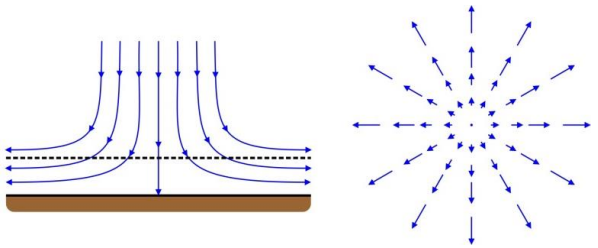
(Leaves ↑↑ flow vector)

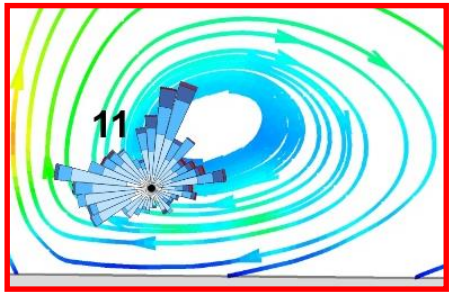

WIND TUNNEL (LDV)
MEAN VELOCITY FIELD
WIND
building
height [m]
40
35
30
25
20
15
streamlines
mean speed [-]
0.4
0.3
0.2
0.1
0
10


WIND TUNNEL (LDV)
WIND STATISTICS
building height [m]
40
35
30
25
20
15
streamlines mean speed [-]
0.4
0.3
0.2
0.1
0
wind roses gust speed [-]
1.0
0.8
0.6
0.4
0.2
0
WIND
0 10 20 m
frequency of occurence [%]
0 5 10 15 20
1
2
3
4
11
26
x
y

SUMMARY

1. Flow and concentration field analyzed for a simplified and real square geometry
2. Main flow features summarized in schematic images
3. Real square shows differences to the simplified one due to asymmetric inflow and varying building heights
4. Simple method to estimate the vertical component from 2D horizontal flow measurements
5. Wind roses are a useful tool to visualize the flow anisotropy in horizontal planes.





Papers

Balczó, M., Lajos, T.: *Flow and Dispersion Phenomena in a Simplified Urban Square.* **Periodica Polytechnica – Civil Engineering 59/3** pp. 347-360. DOI: 10.3311/PPci.7852

Balczó M, Tomor A: *Wind tunnel and CFD study of wind conditions in an urban square.* **IDOJARAS - Quarterly Journal of the Hungarian Meteorological Service 120/2** - accepted paper

Thank you for your attention!

MŰEGYETEM 1782

Theodore von Kármán Wind Tunnel Laboratory

Acknowledgements

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