Dynamics of a street canyon flow from idealized field and wind tunnel experiments

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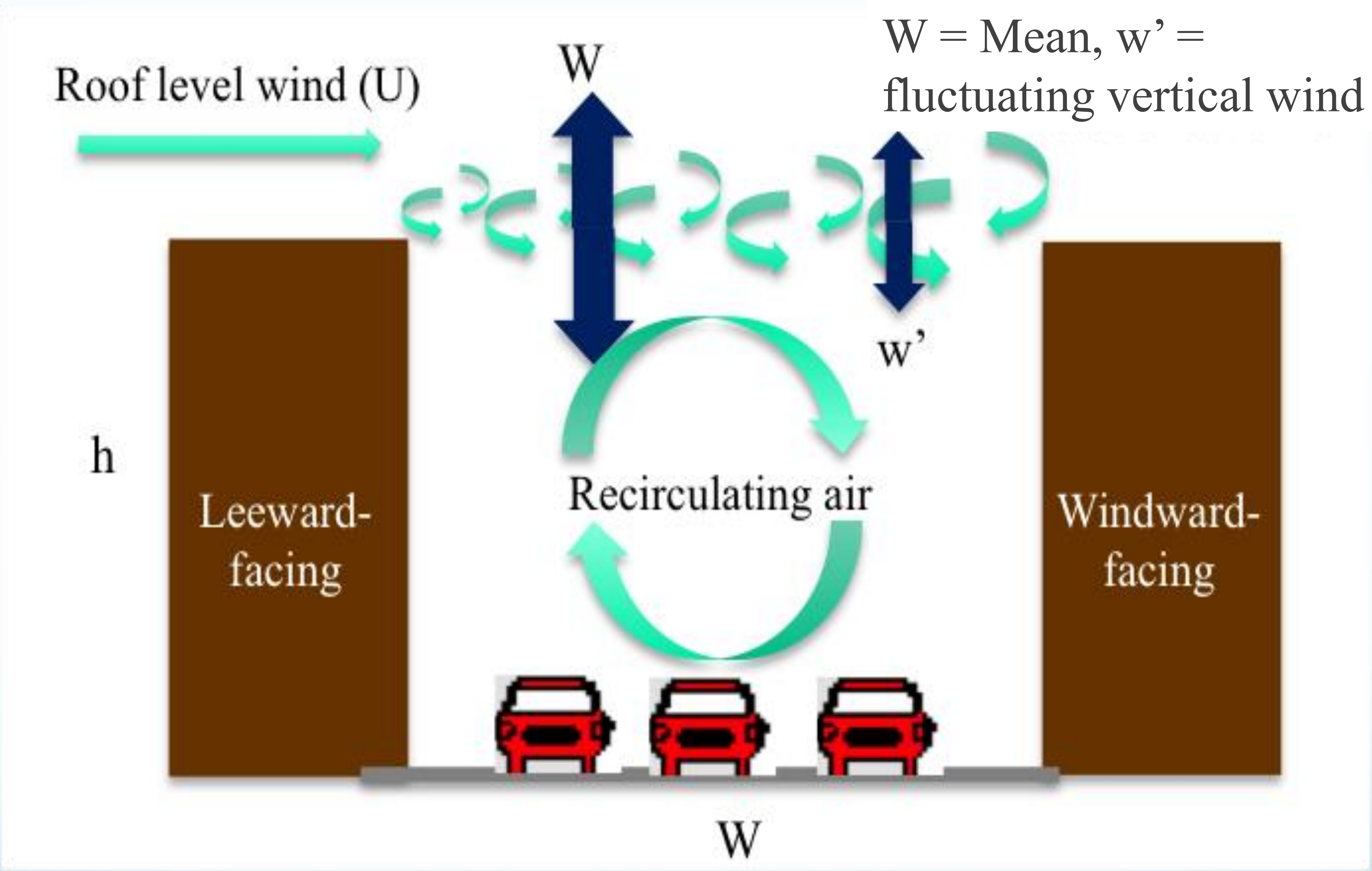
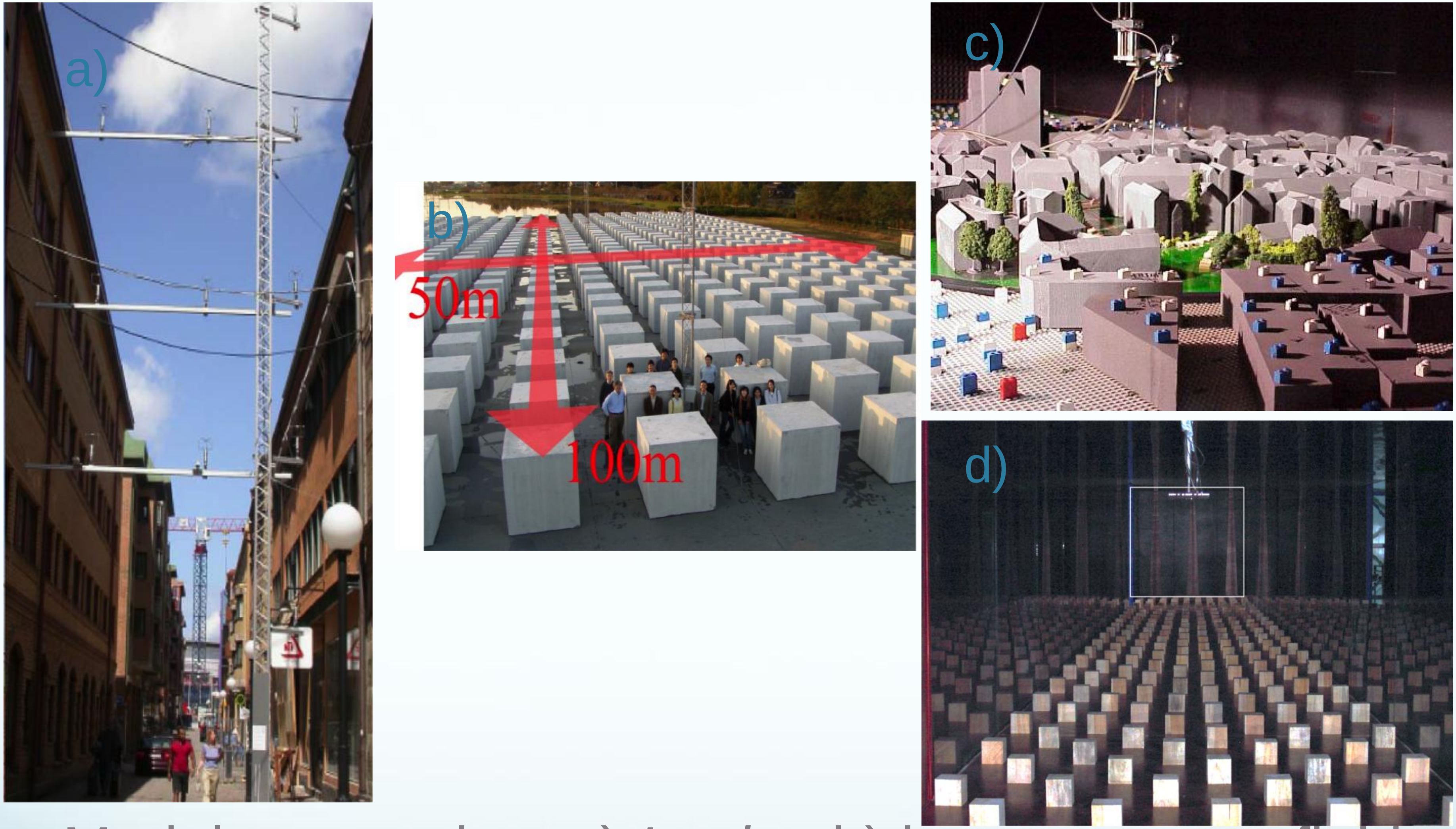


Mean flow pattern in urban street canyon

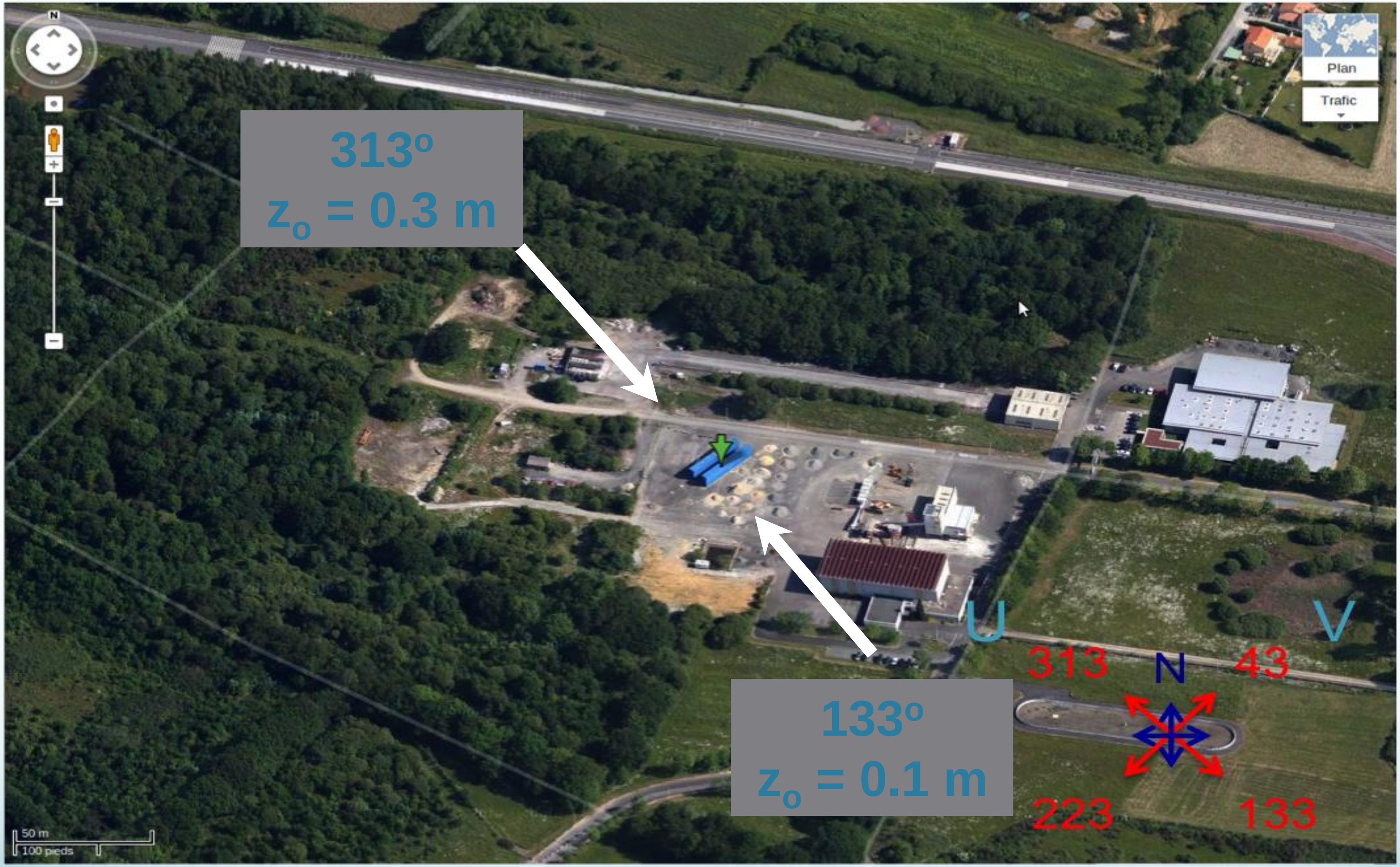


Model approaches a) *In-situ*; b) homogeneous field model; c) site-specific wind tunnel model; d) homogeneous wind tunnel model

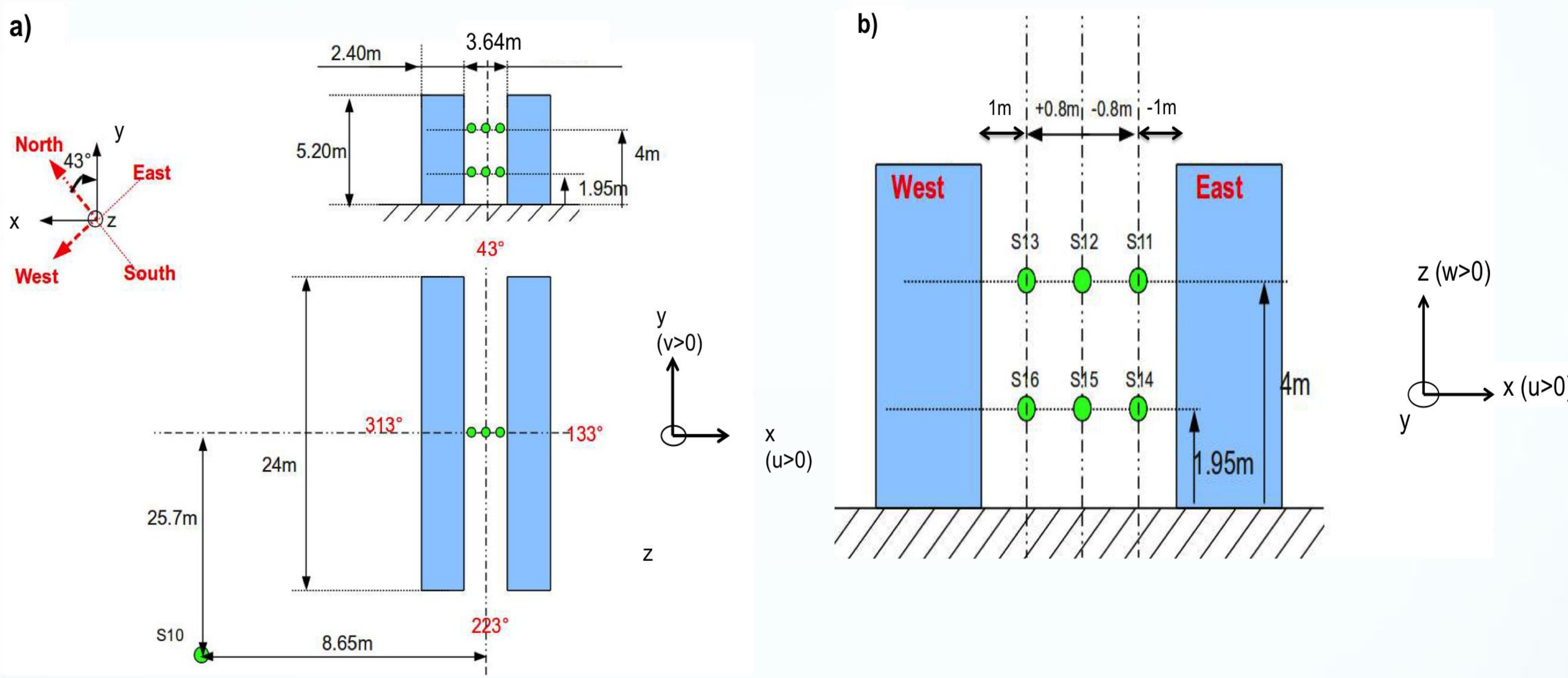
Today's Agenda

1. Experimental details
2. Results and discussion
   - Comparison of mean statistics
   - Influence of ambient conditions
   - Stochastic Estimation Model
3. Conclusions

Experimental details



Field canyon and surrounding landscape (Google Maps)

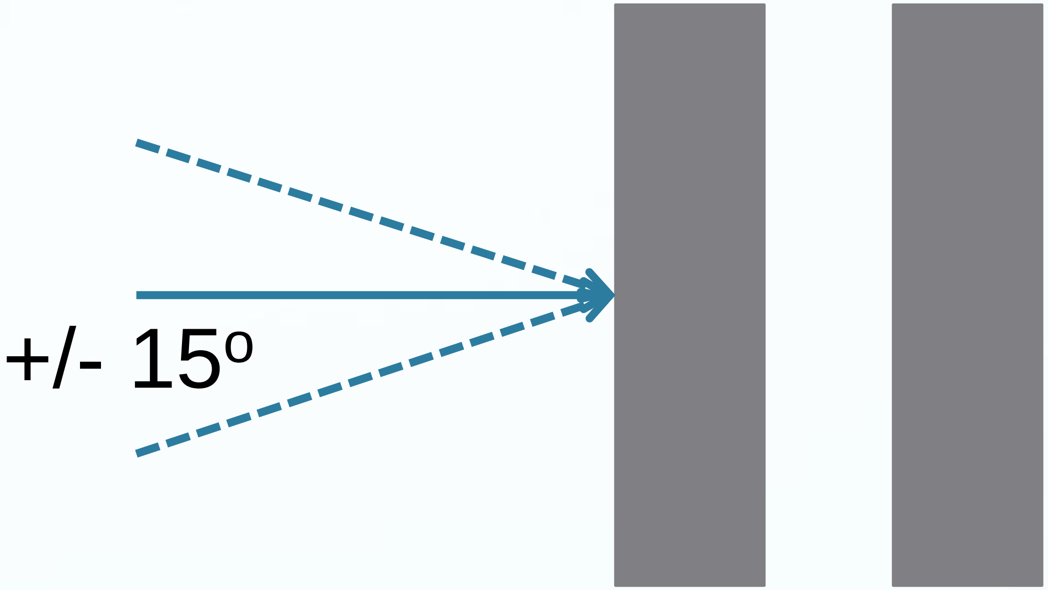


a) Side and aerial view of canyon and mast; b) side view of canyon with sonic anemometer spacing

3D sonic anemometers frequency = 20 Hz

<u>Selection Criteria</u>

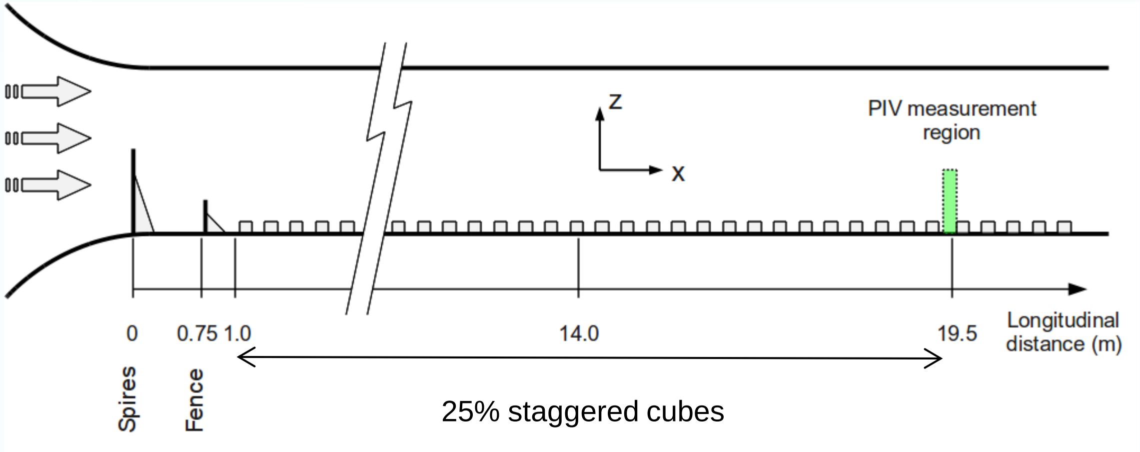
- +/- 15º from 133º and 313º
- Monin Obukhov L > 1000m
- > 30 minute period
- $V/U_{10} < 10\%$



- 12 instances from 133º direction
- 5 instances from 313º direction

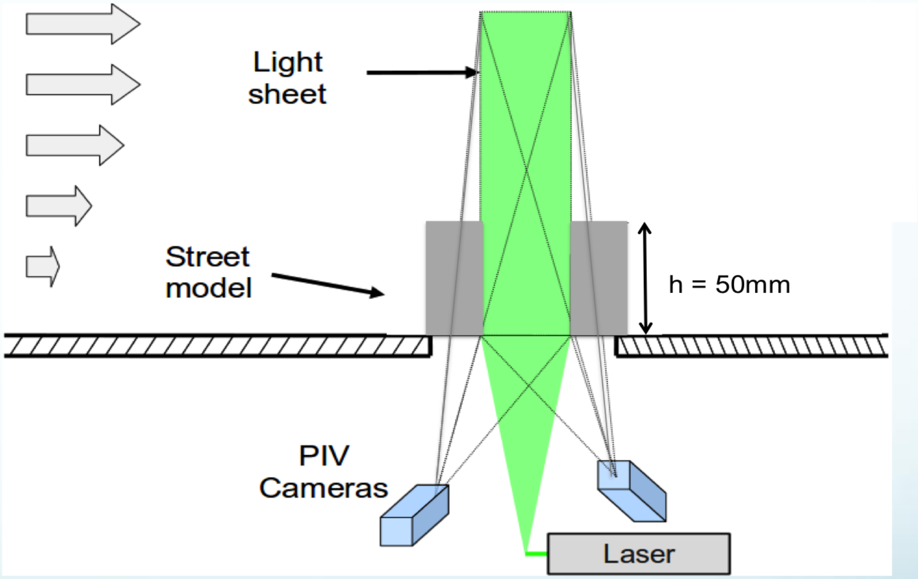
Total length = 37.5 m
Working section length = 24 m
Cross section = 2 m x 2 m

Max. velocity = 10 m/s
Turb. intensity = 0.5%



Wind tunnel set-up

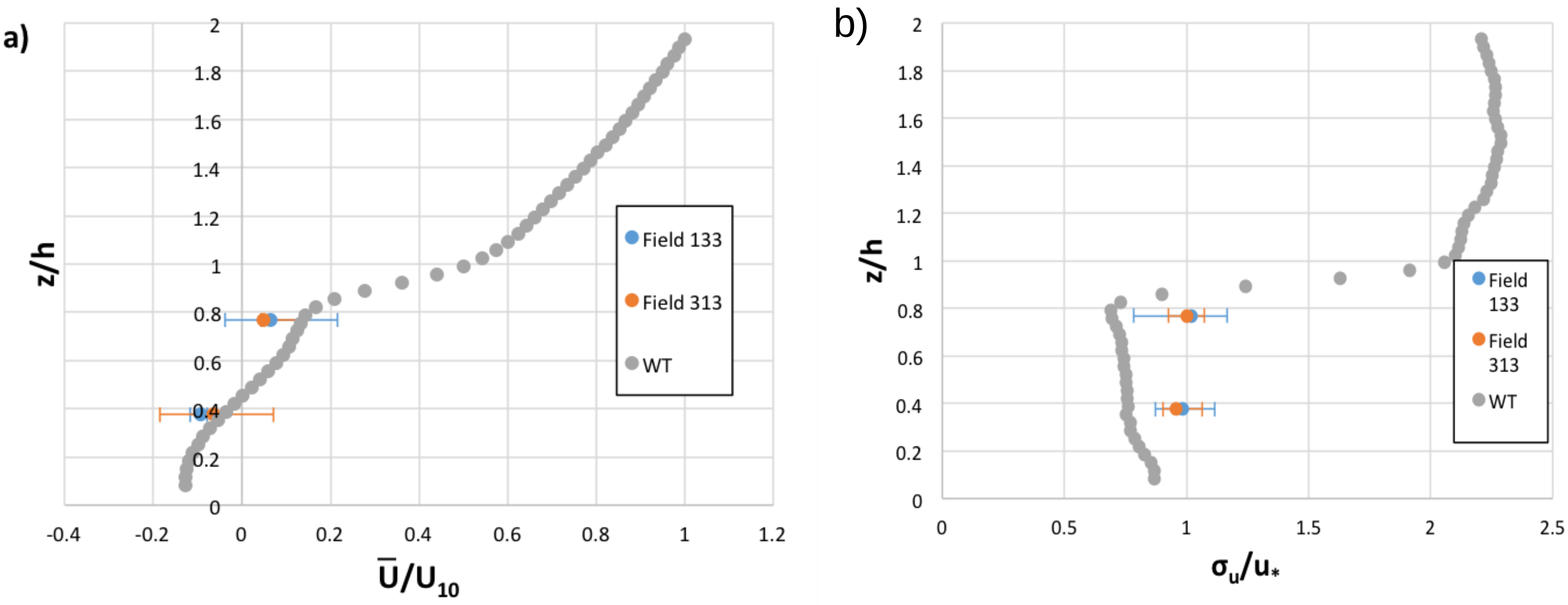
- Frequency = 7 Hz
- Image pairs = 5000
- Vector spacing (x, y) = (0.84 mm, 1.68 mm)



Stereoscopic PIV set-up

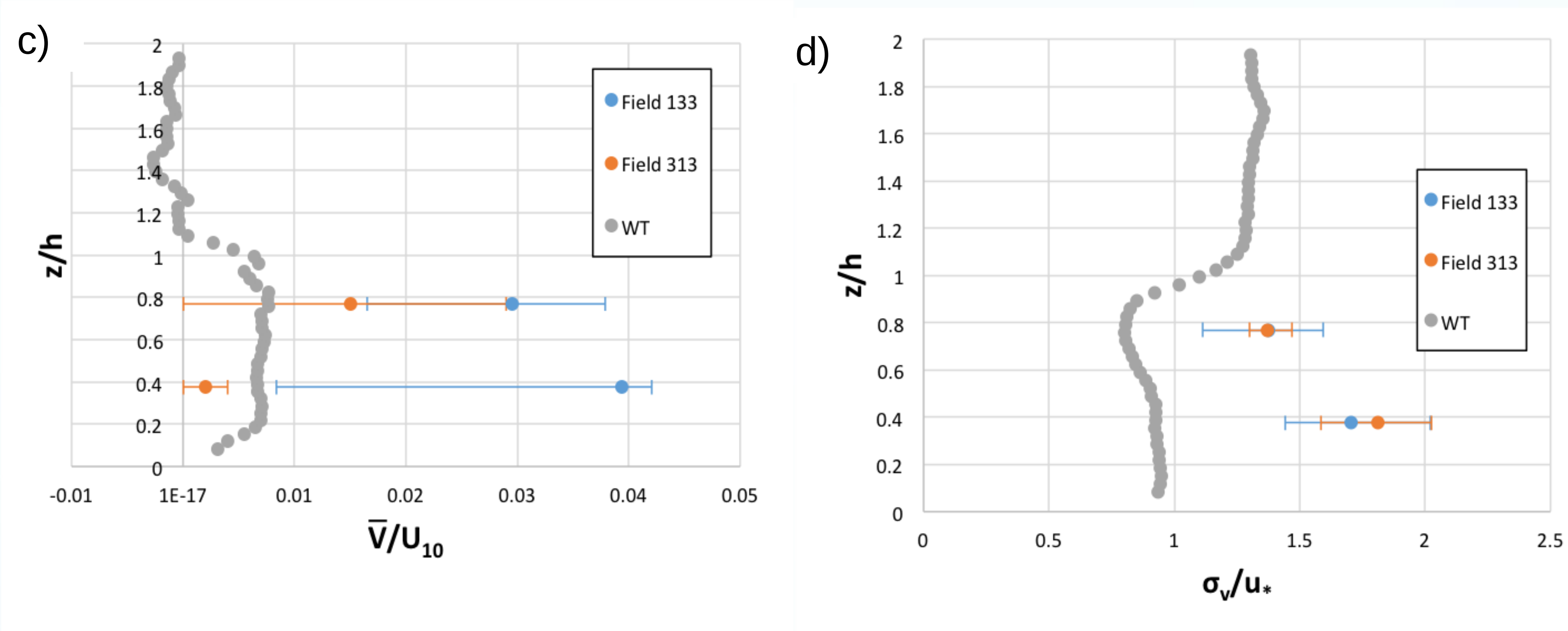
Results and Discussion

Mean Turbulence Statistics



a) Mean streamwise velocity; b) streamwise turbulence intensity at x/W = 0, y/h = 0

- Reverse flow present in wind tunnel and field
- 20% underestimation of streamwise turbulence intensity

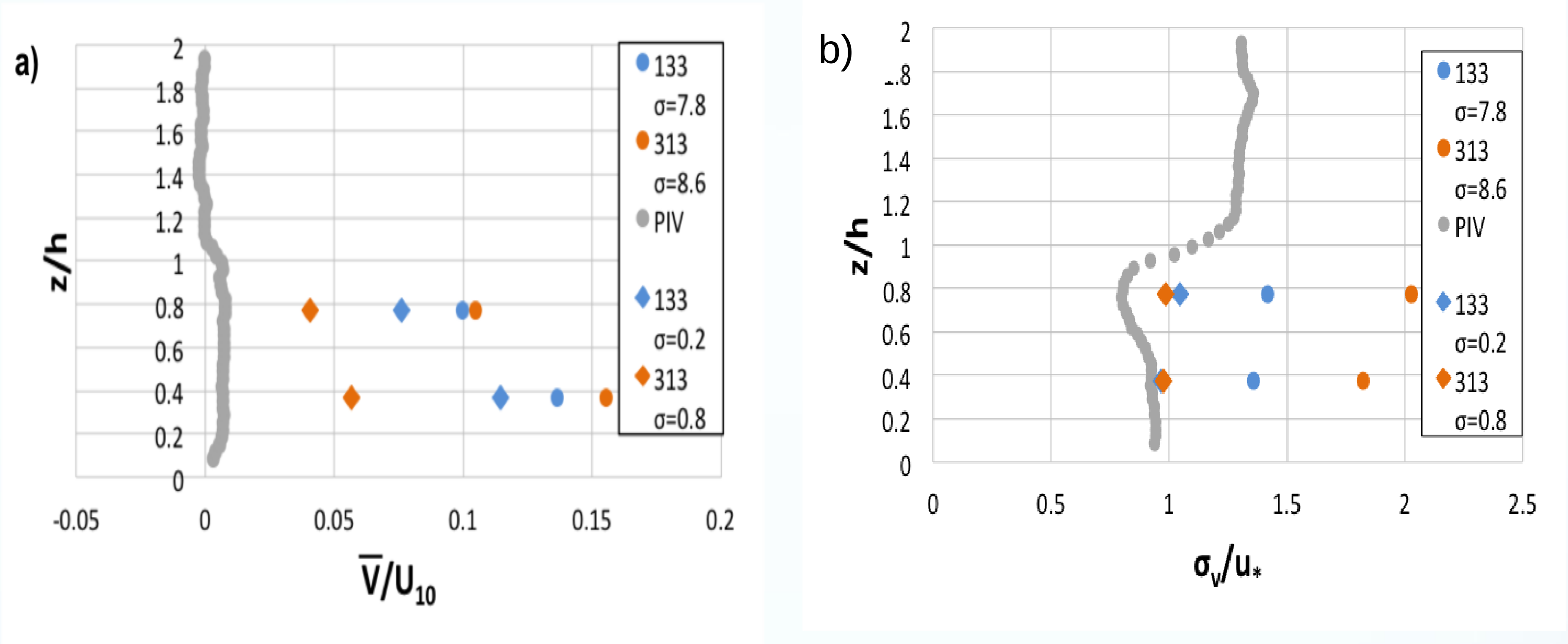


c) Mean spanwise velocity; d) spanwise turbulence intensity at x/W = 0, y/h = 0

- Large discrepancy, up to a factor of 100, in spanwise velocity
- Spanwise turbulence intensity has discrepancy up to 100%

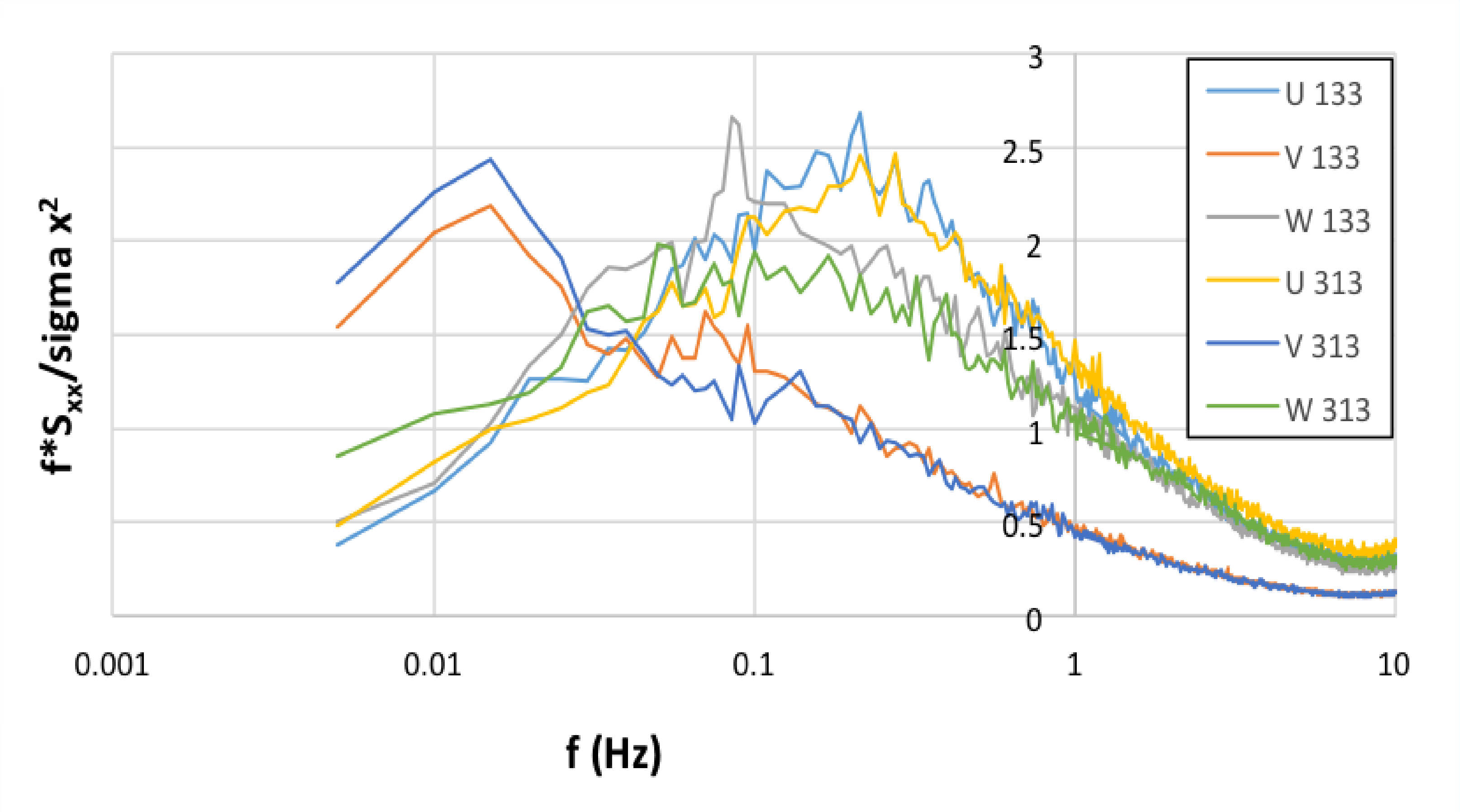
Results and Discussion

Influence of ambient conditions on canyon statistics



a) Mean spanwise velocity; b) spanwise turbulence intensity at centre of canyon (x/W = 0, y/h = 0)

- Improvement up to a factor of 6 for mean spanwise velocity
- Large discrepancy suggests angle of incidence contributing factor to mean spanwise velocity
- Wind direction changes increase spanwise turbulence intensity



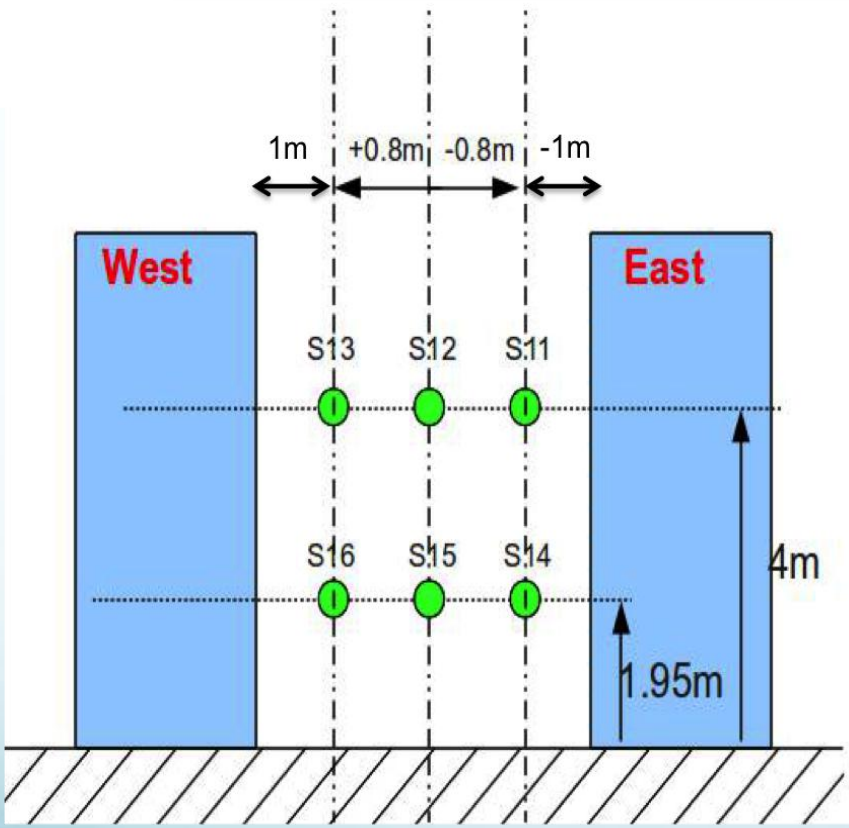
Ensemble averaged turbulence spectra x/W = -0.22, y/h = 0 and z/h = 0.77

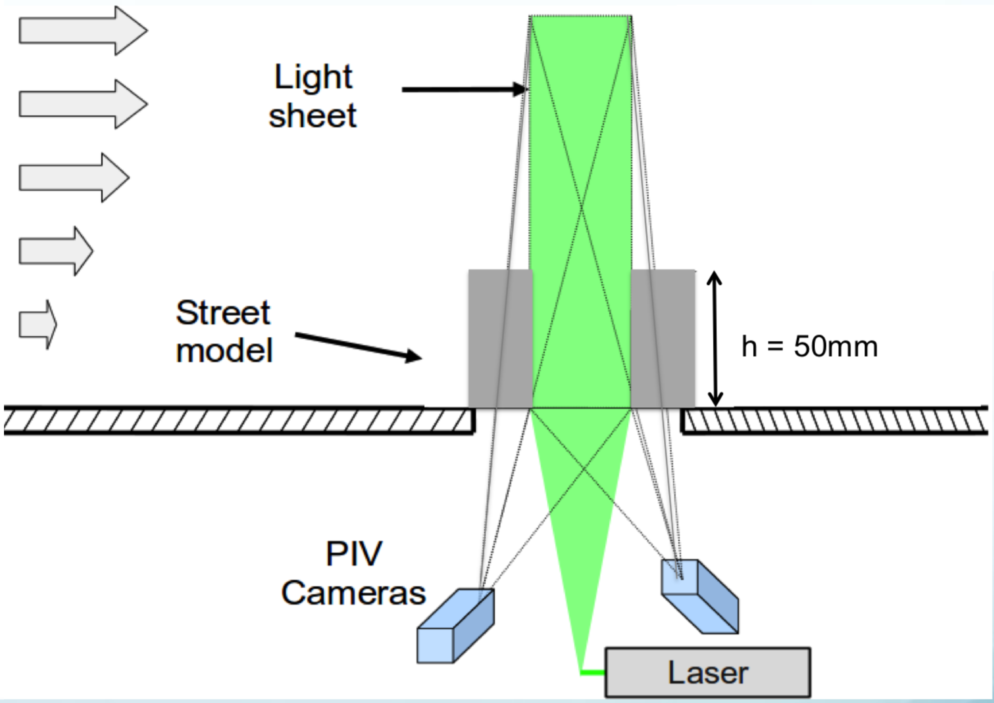
- Low frequency motions present in spanwise spectra

Results and Discussion

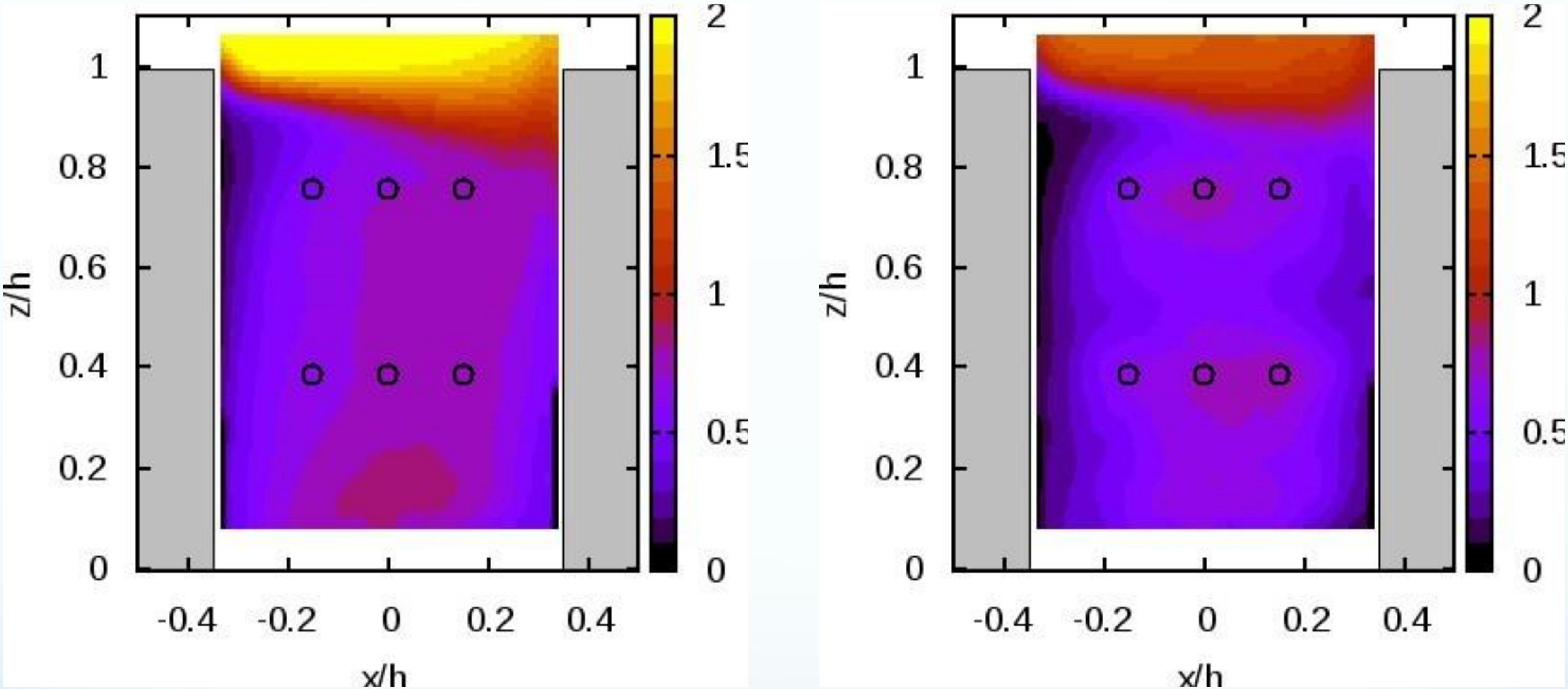
Stochastic Estimation

$$\tilde{u}_l(x,y,z,t) = \sum_{j=1}^{N_c}\sum_{l=1}^{N_{ref}} A^i_{jl} u^{ref}_j(x_l,y_l,z_l,t) + \sum_{j,l=1}^{N_c}\sum_{m,n=1}^{N_{ref}} B^i_{jlmn} u^{ref}_j(x_m,y_m,z_m,t) u^{ref}_k(x_n,y_n,z_n,t)$$

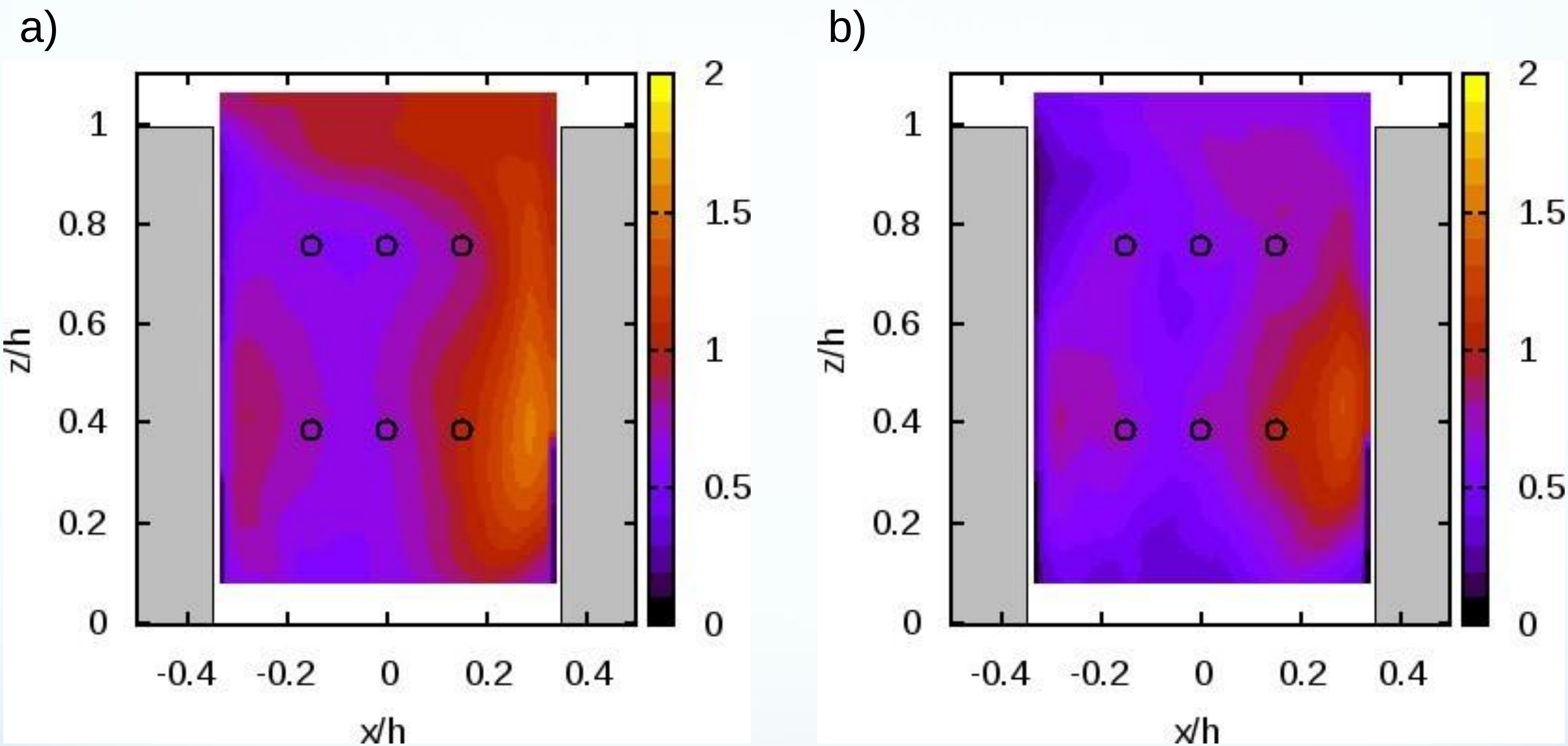




a) b)

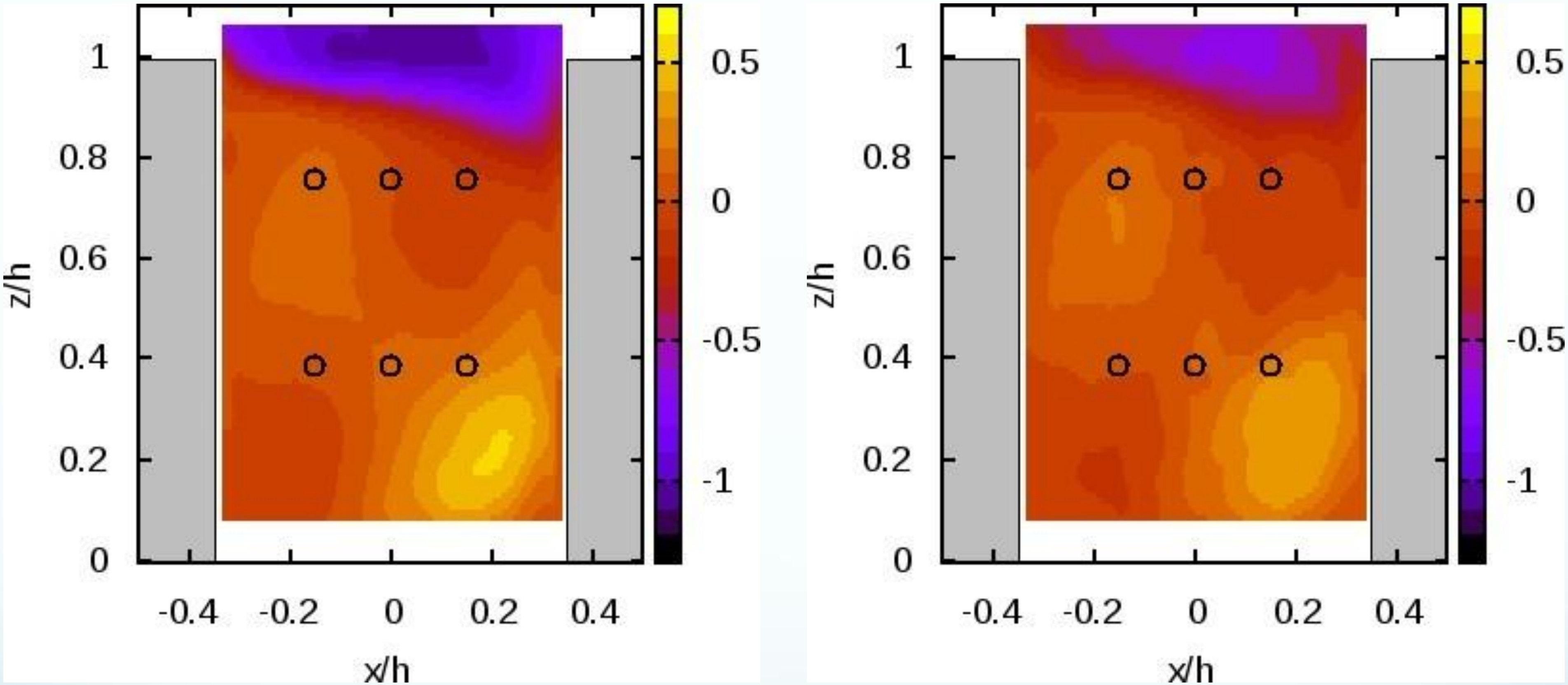


σ_u of the a) PIV b) QSE using 6 reference points (○) located at the corresponding sonic anemometers in the field experiment

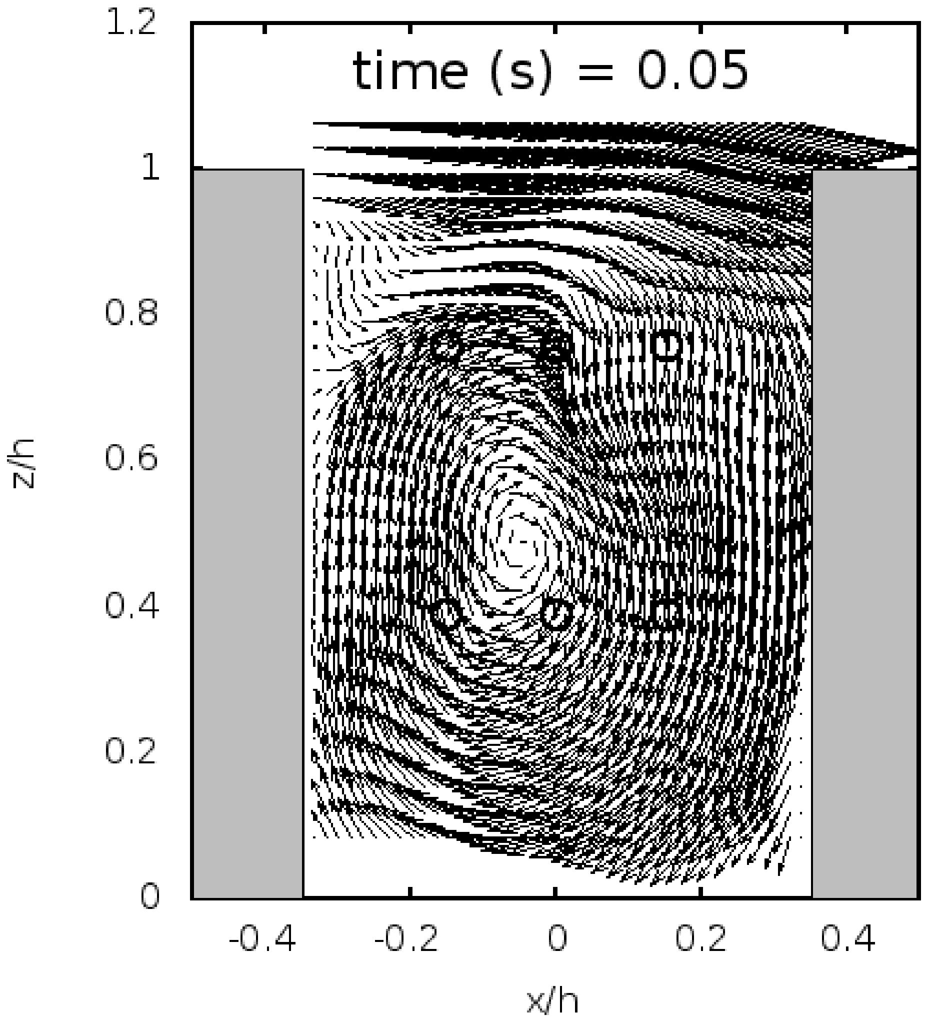


σ_w of the a) PIV b) QSE using 6 reference points (○) located at the corresponding sonic anemometers in the field experiment

a) b)



u'w' of the a) PIV b) QSE using 6 reference points (○) located at the corresponding sonic anemometers in the field experiment


time (s) = 0.05
1.2
1
0.8
0.6
0.4
0.2
0
z/h
-0.4
-0.2
0
0.2
0.4
x/h

Conclusions

Conclusions

- Mean turbulence statistics of an idealized field experiment are well predicted by a wind tunnel model of equivalent dimensions except mean spanwise velocity and turbulence intensity
- This is the first attempt to combine spatially well-resolved PIV data obtained from a wind tunnel experiment with time-resolved velocity measurements from a field experiment
- This model offers great potential for the prediction of the ventilation inside the street canyon and for the design of field experiments

References

Blackman, K., Perret, L. and Savory, E. (2015) Field and wind tunnel modeling of an idealized street canyon flow. Atmospheric Environment. doi: 10.1016/j.atmosenv.2015.01.067

Guillaume G., Ayrault C., Berengier M., Calmet I., Gary V., Gaudin D., Gauvreau B., L'hermite Ph., Lihoreau B., Perret L., Picaut J., Piquet T., Rosant J.M., Sini J.F., 2012. Micrometeorological effects on urban sound propagation: a numerical and experimental study. All Glo Sus, 19, 109-119.