Statistical analysis of velocity measurements in an atmospheric boundary layer in wind tunnel

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1/ Context

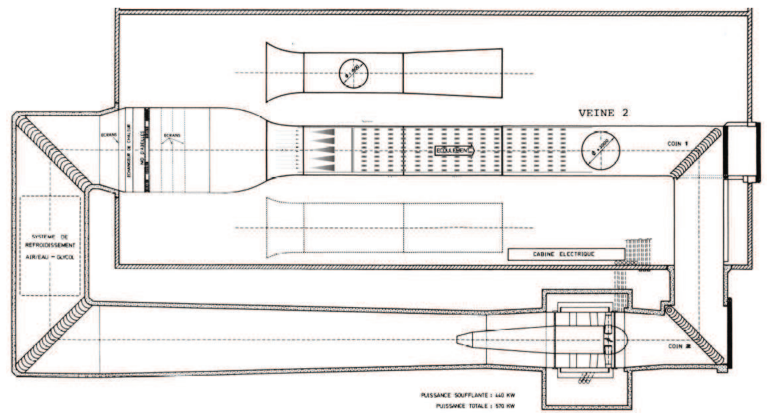
We focus on the statistical properties of the longitudinal component of the flow velocity in an Atmospheric Boundary Layer (ABL). This investigation goes beyond the classical characterisation of ABL's, which are usually limited to the study of the mean values, turbulence intensities and power spectral densities of the flow velocities [1].

In the scope of wind engineering studies, it is usually admitted that the wind flow is gaussian, while non-gaussian peak pressures are the sole consequences of the aerodynamic signature of the building.

Preliminary measurements are presented: we show that the assumption of gaussianity is not verified in the simulated ABL. The final objective is to study the effect of such flow conditions on the aerodynamic loading of a vertical structure and to make the link with the common practice approach that considers the incoming wind as a gaussian process.

2/ Experimental set-up

The multidisciplinary wind tunnel of University of Liège is set into its wind engineering configuration: Goettingen type wind tunnel with test section dimensions equal to 13.5 m × 2.5 m × 1.8 m.



The ABL is created using 5 spires (1.15 m high), a castellated fence (0.15 m high) and wooden blocks (0.05 m × 0.05 m × 0.1 m), covering the floor of the wind tunnel up to 1 m upstream the measurement location. Two single component Hot-Wire Probes (HWP's) are translated vertically at the center of the test section. The two HWP's are separated by 0.3 m in the transversal direction to the wind (y-axis).

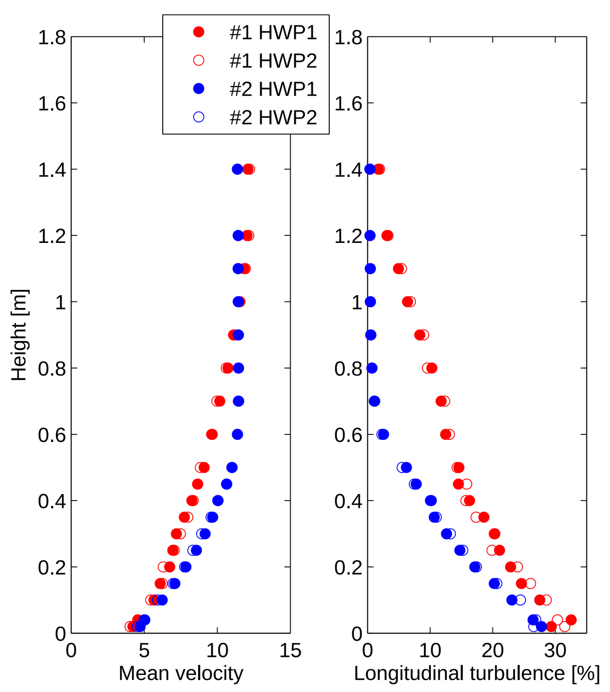
Hot-Wire type	1D (Dantec Dynamic)
Acquisition frequency	10kHz
Measurement duration (per position)	3 min
18 vertical positions	0.04 m - 1.4 m

3/ Test cases

Two configurations are selected and analysed:

	Config. #1	Config. #2
Spires	✓	✗
Fence	✓	✗
Blocks	✓	✓
Ref. airspeed at 1.4 m	12.2 m/s	11.8 m/s

The variation of the mean value and turbulence intensity of the horizontal velocity component with height are shown here. Measurements by the two HWP's are shown for both configurations. Config #1 corresponds to a category III rugosity terrain, while config #2 is comparable to a Boundary Layer (BL) developing over a flat plate.



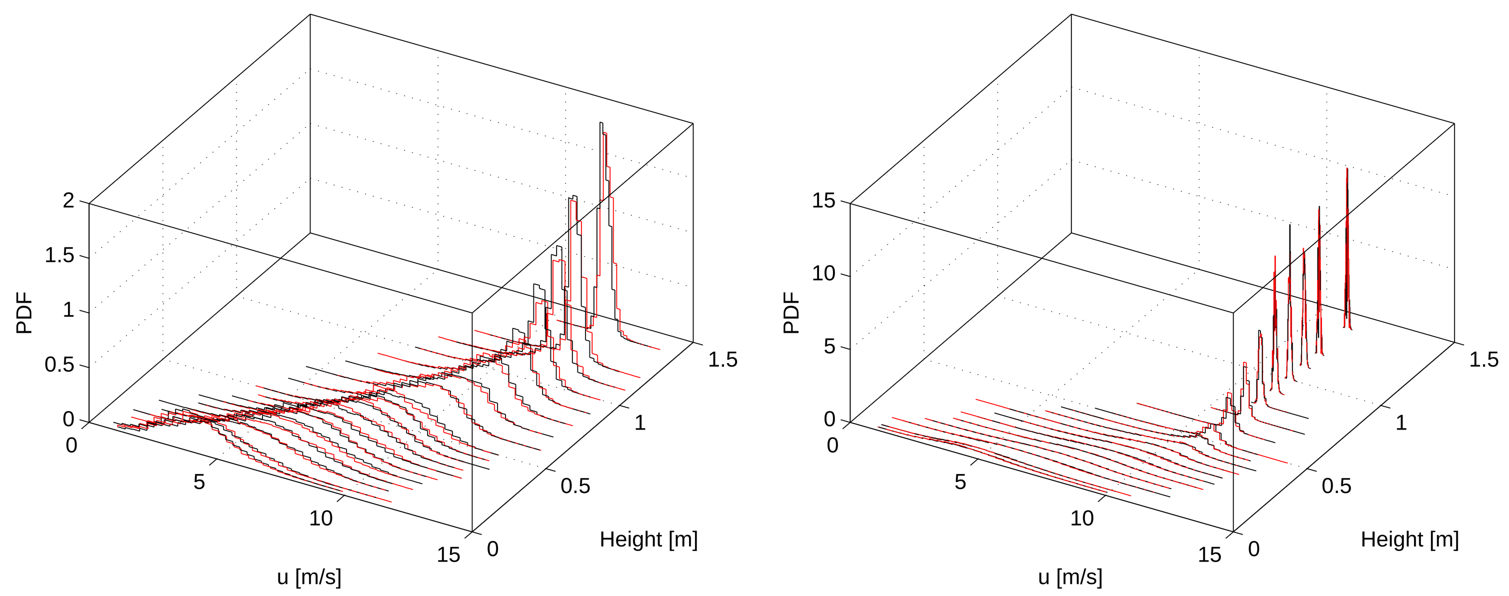
4/ Results

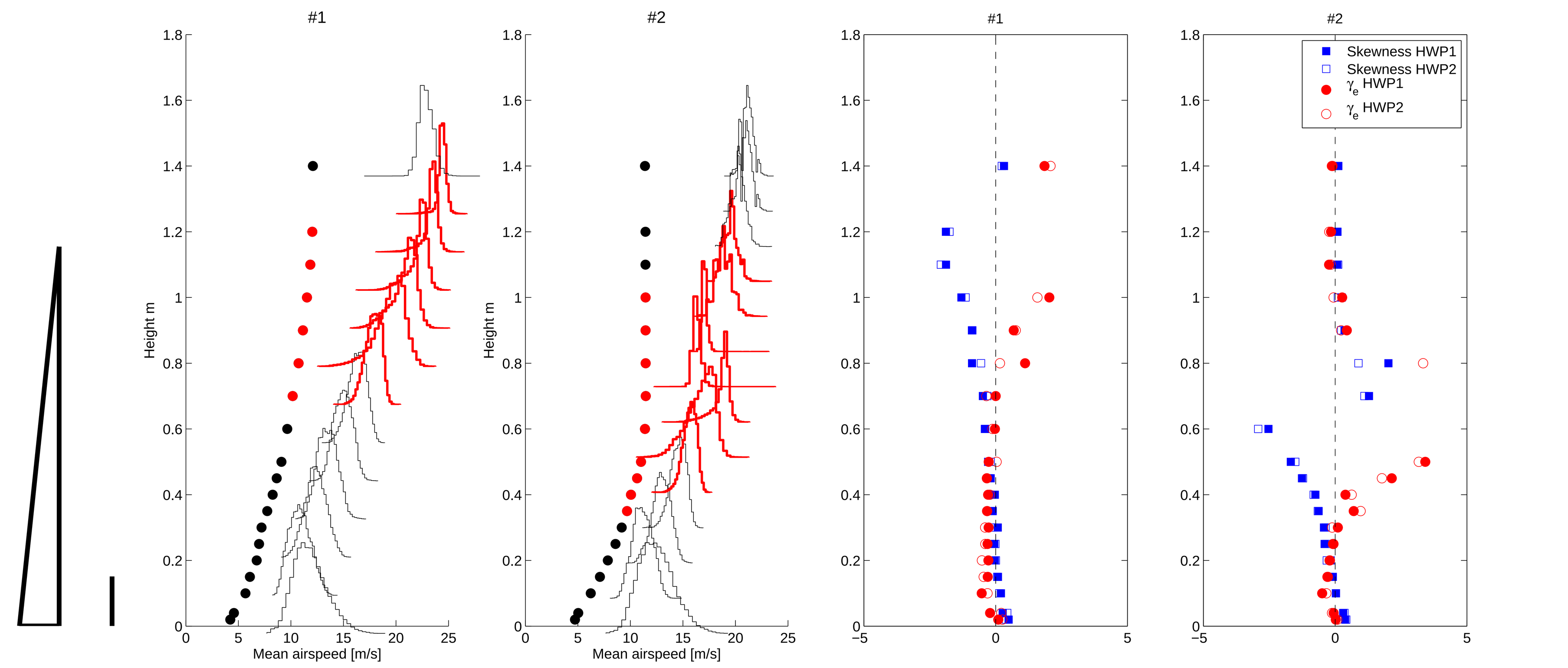
The Probability Density Functions (PDF's) of the u-component of velocity are shown in the right plots: non-gaussian PDF's are observed for each configuration (see red traces). The lack of symmetry of the these distributions is quantified using the skewness and γ_e indicators (null if gaussian).

Config. #1: asymmetry appears above 0.8 m, up to 1.4 m (maximum measurement height), where the distribution seems to retrieve its symmetry.

Config. #2: asymmetry of the PDF's is observed between 0.35 m and 1 m. Above 1 m, the free stream is reached and the distribution is gaussian with a sharp shape.

The plots below show the PDF's for both configurations. The shapes of the PDF's is similar for both HWP's, confirming the uniformity of the ABL along the y-axis at the measurement location.

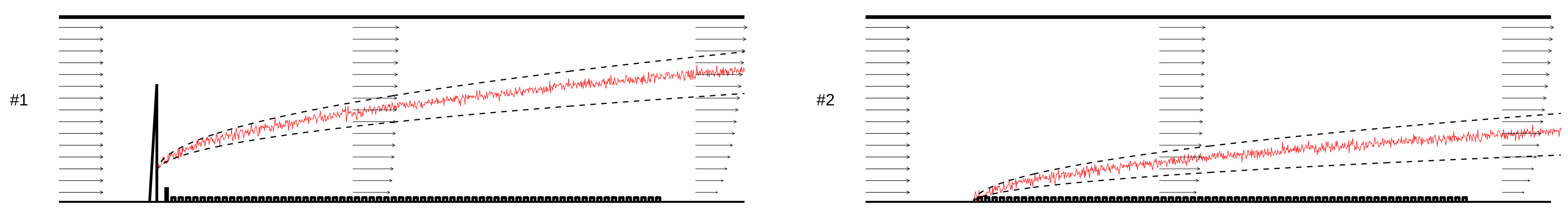




In the lower part of the BL, the sign change of the skewness observed around 0.2 m height traduces the end of the roughness sub-layer, which is only due to the blocks (common in the two configurations) [2].

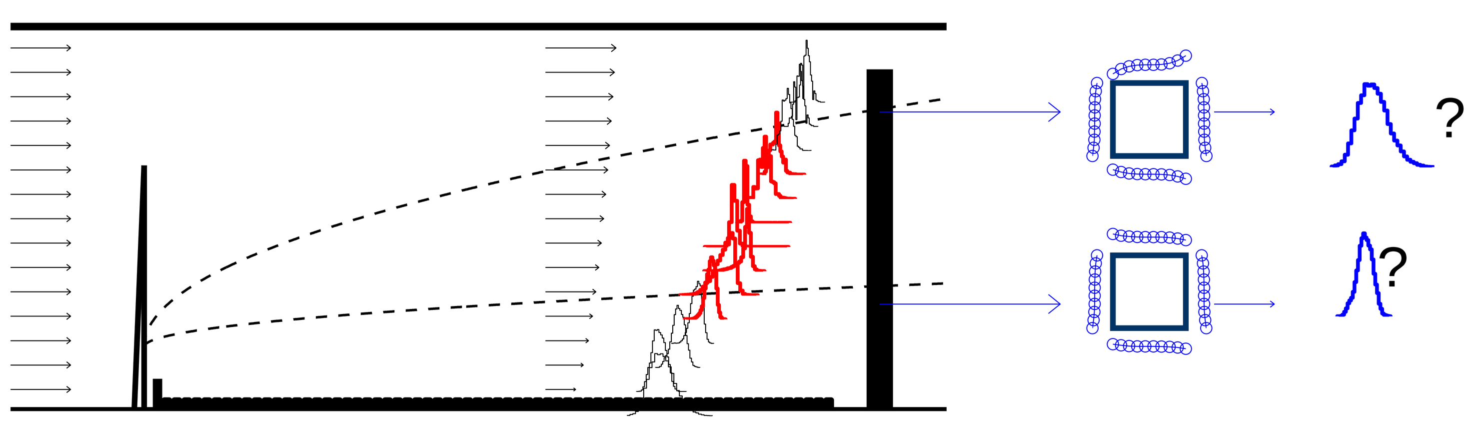
5/ Discussion

The observed PDF's might be explained by the random motion of the shear layer, separating the ABL from the upper part of the test section where the flow is not perturbed by the rugosities. The situation is sketched here, where the red chaotic traces represents the position of the shear layers at a given time for both configurations. It is believed that the position of this red trace oscillates randomly between the upper and lower dashed lines. Hence, above a certain height, a point will see **intermittent flows** (BL and free stream), which results in the observed non-gaussian distributions.



6/ Next steps

A new test campaign is planned on a square high rise building held statically. Unsteady pressure distributions will be measured at different heights using a multi-channels PSI sensor. Their statistical properties will be analysed regarding the characteristics of the incoming wind, as sketched below. Extension to aeroelastic models is foreseen to evaluate the effect of non-gaussianity of the ABL on the dynamic responses of the structure.



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