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Bluff body aerodynamics of the Thies Laser Precipitation Monitor investigated using CFD and wind tunnel measurements

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INCIPIT Metrology for non-catching rain instruments

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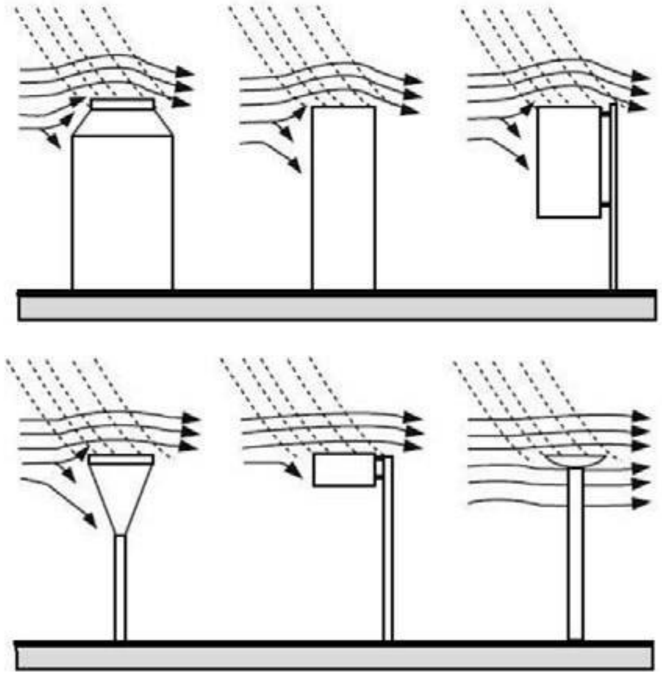
Wind-induced error on precipitation measurements

Wind has been recognized as the most influent environmental parameter that affects precipitation measurements. Wind is deflected by the gauge body and the resulting modification of the airflow around the gauge affects the hydrometeor trajectories.

For traditional catching-type gauges different studies were performed to quantify the influence of wind on precipitation measurements, both in the field (Nitu et al., 2018, Pollock et al. 2018) and using numerical simulations (Colli et al. 2015; 2016a,b).



Non-Catching type precipitation gauge

The use of non catching-type precipitation gauge rapidly increased in the last years, due to the capability of these instruments to obtain additional information apart from rainfall intensity (e.g. drop size distribution and drop fall velocities) and the low required maintenance, making them suitable to be employed in automatic weather stations.

Despite these capabilities the shape of these kind of instruments is usually complex and not axisymmetric, and the measurement is affected by the aerodynamic response of the gauge body in windy conditions.

In this work, we focus on the Thies-LPM disdrometer by performing numerical simulations and wind-tunnel experiments under two wind directions to highlight the aerodynamic influence of the gauge body on the measuring area.

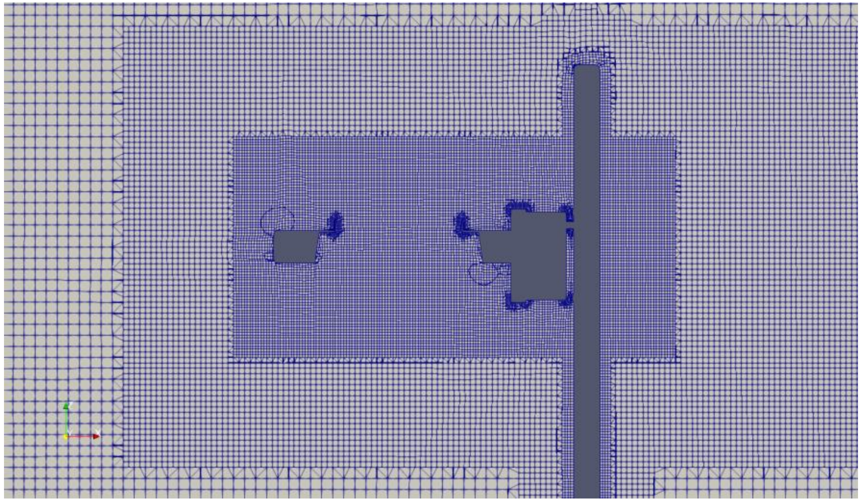
Thies – Laser Precipitation Monitor

Thies CLIMA

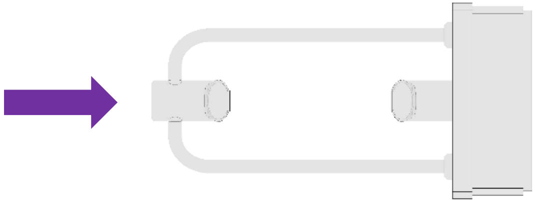
Numerical simulations

Simulations were run using the OpenFOAM package to numerically solve the URANS equations with a k-ω SST turbulence model.

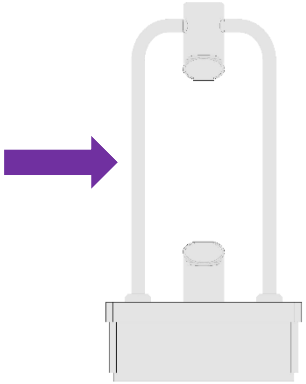
- Wind velocity: 5 m/s and 10 m/s
- Frontal and lateral flow directions



Frontal flow



Lateral flow



The computational mesh is composed of 2.66 10^6 cells, and the dimensions of the simulated domain are 8 x 4 x 3 m.

Wind tunnel experiments

University of Genoa DICCA wind tunnel

- Measurement chamber size: 1.7 x 1.35 x 8.8 m
- Max air speed 40 m/s
- Installed power 132 kW

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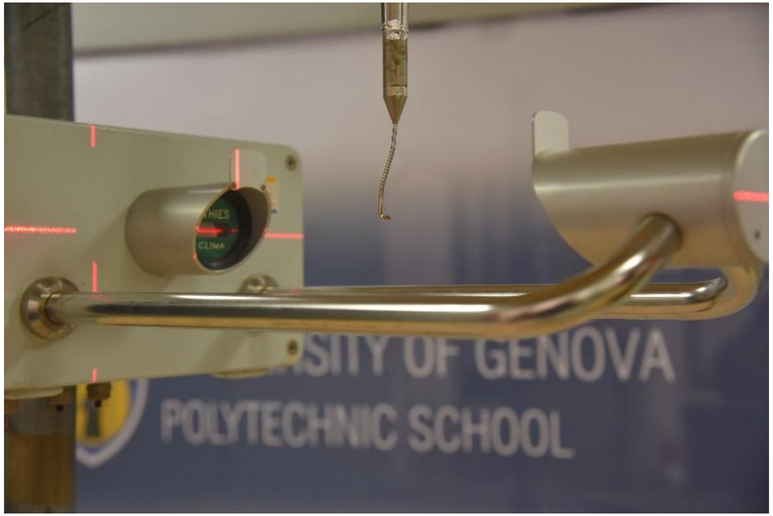
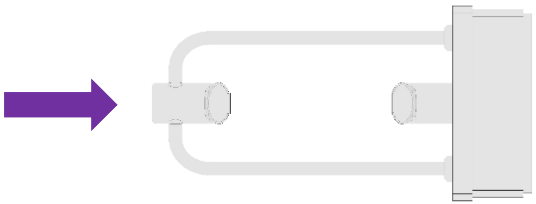
Local wind velocity measurements performed using a *Cobra* multi-hole pressure probe at different positions around the instrument

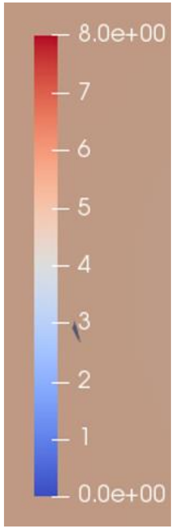


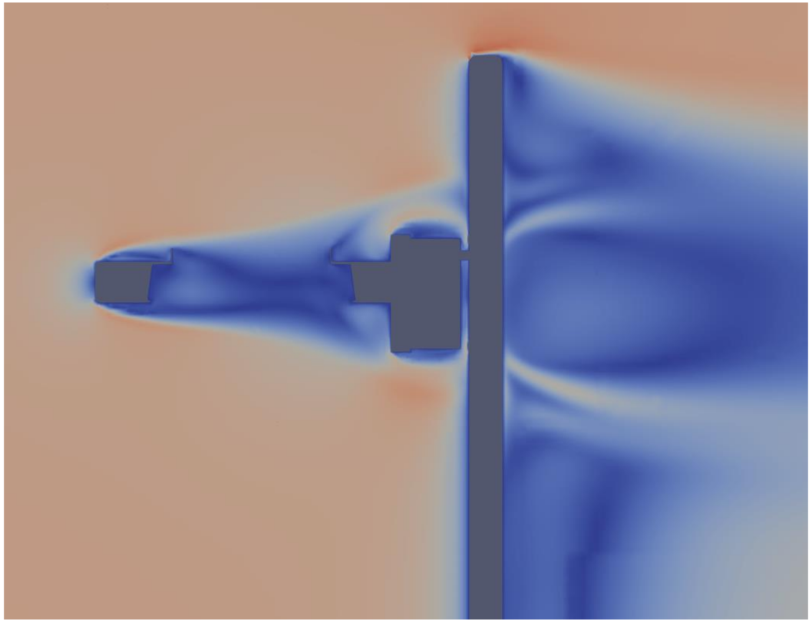
Numerical simulation results



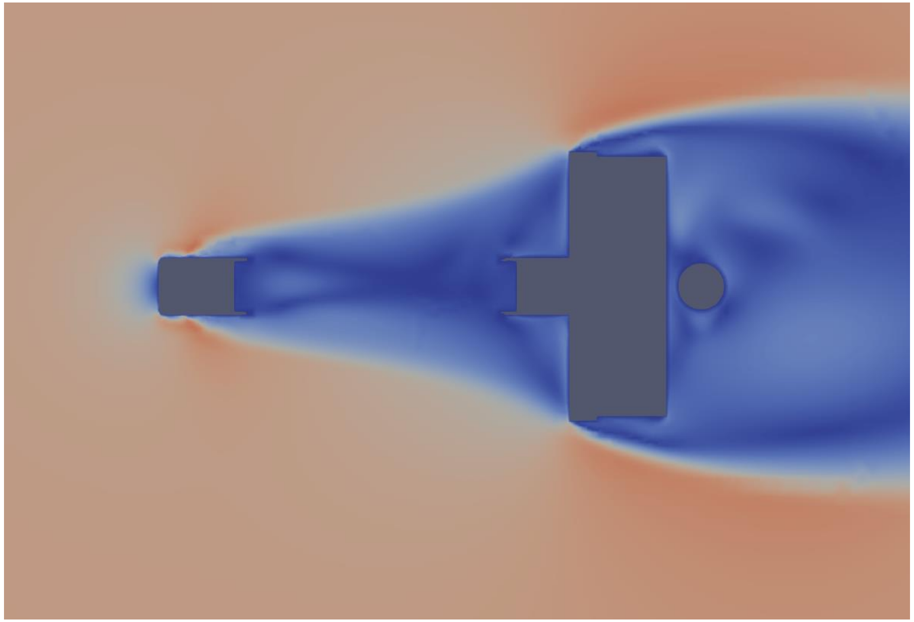
Velocity field near the instrument for a free-stream velocity of 5 m/s

U_{mag} [m/s]





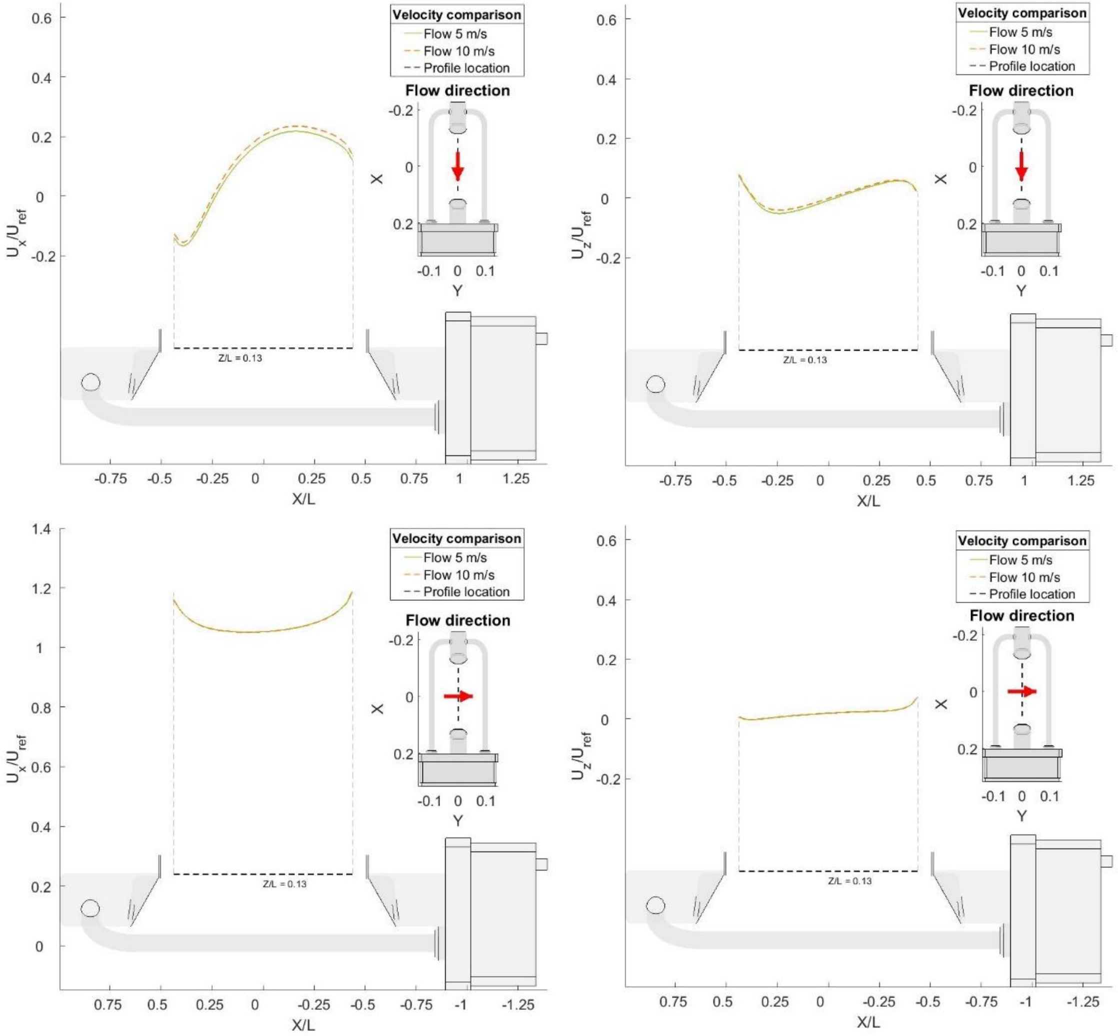
Vertical section



Horizontal section

Frontal flow

Lateral flow



Scalability of numerical simulation

The comparison between non-dimensional velocity profiles at 5 m/s and 10 m/s shows minimal differences between simulations, in particular for a lateral flow, where the profiles are almost coincident.

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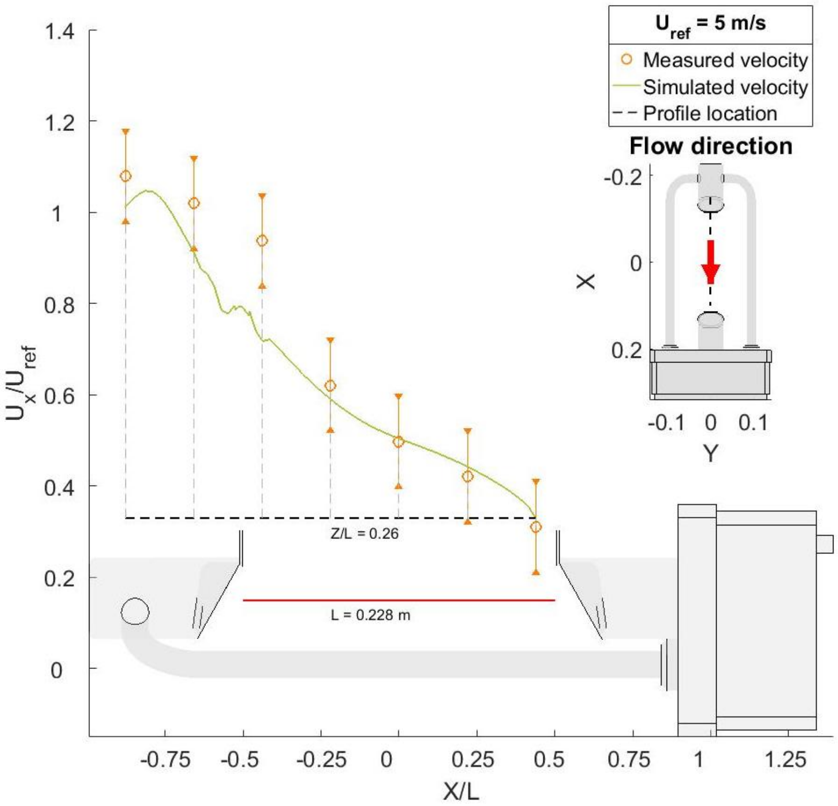
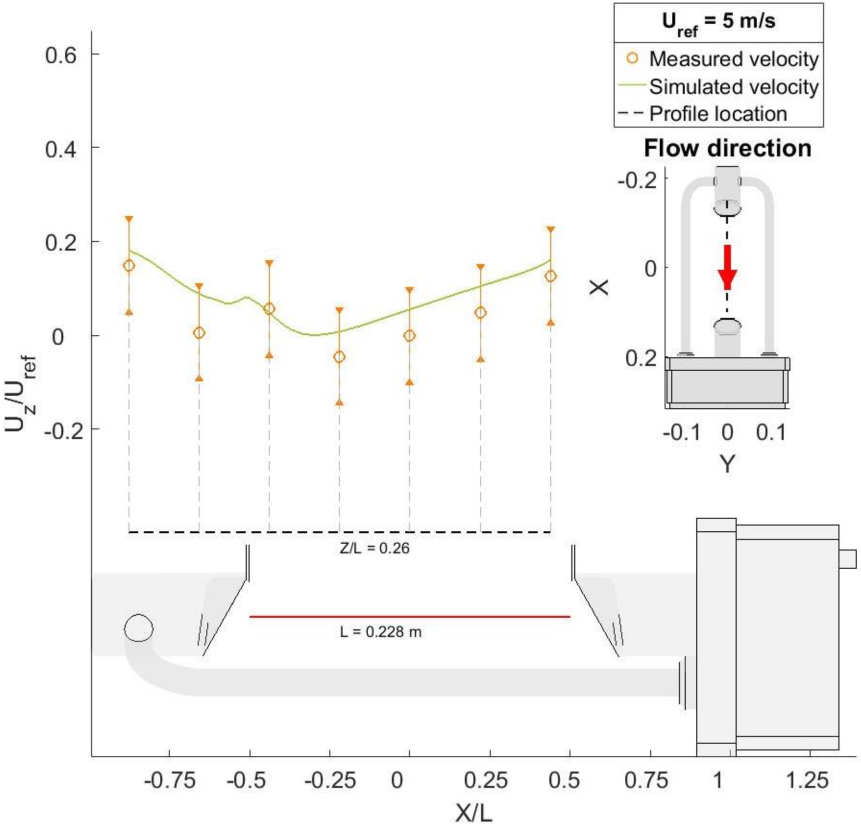
Validation of numerical simulation

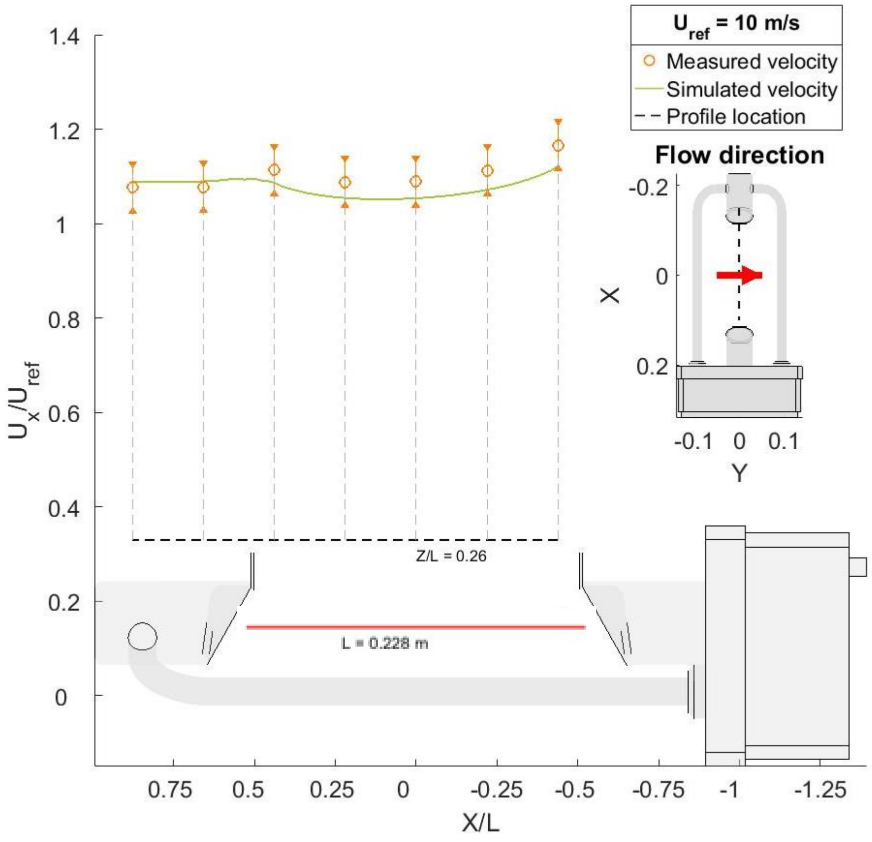
Comparison between cobra measurements and simulated velocity profiles: **Frontal flow**

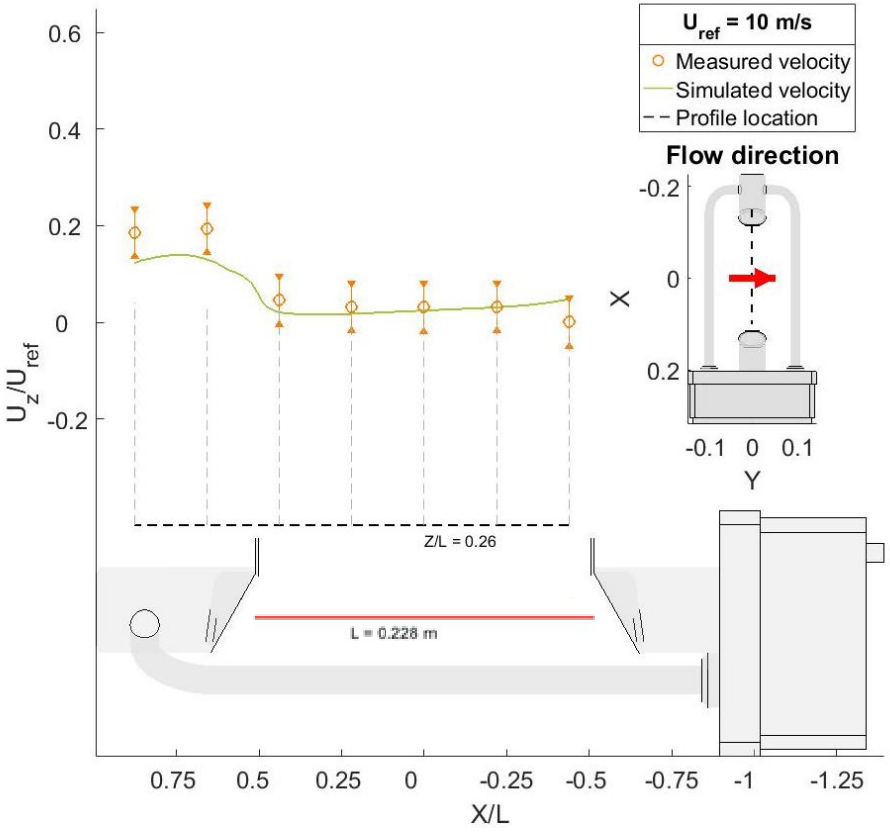




Validation of numerical simulation

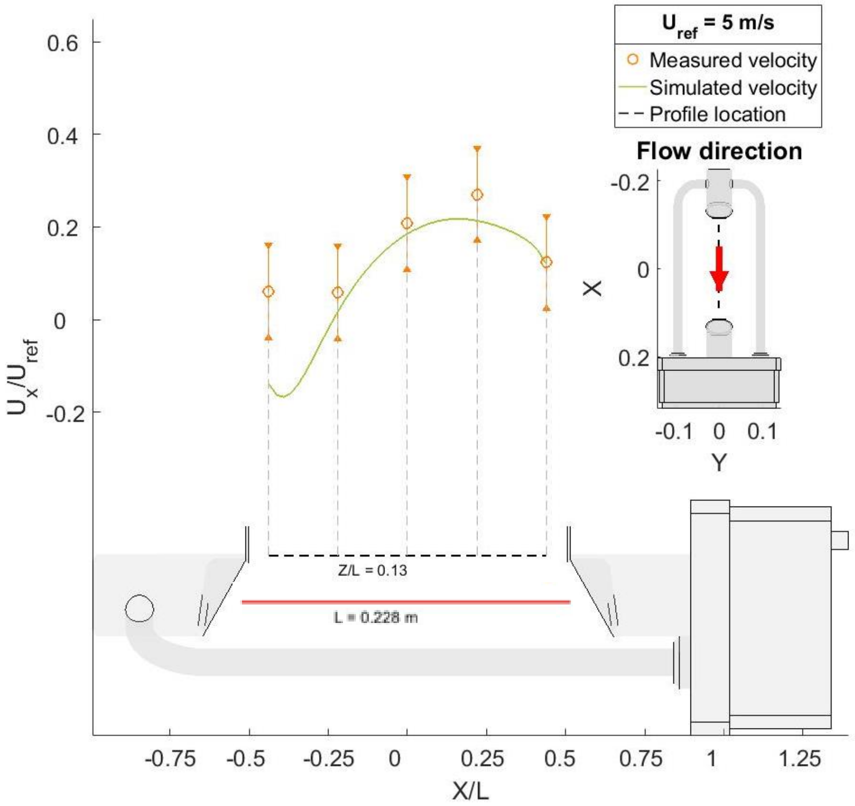
Comparison between cobra measurements and simulated velocity profiles: **Lateral flow**

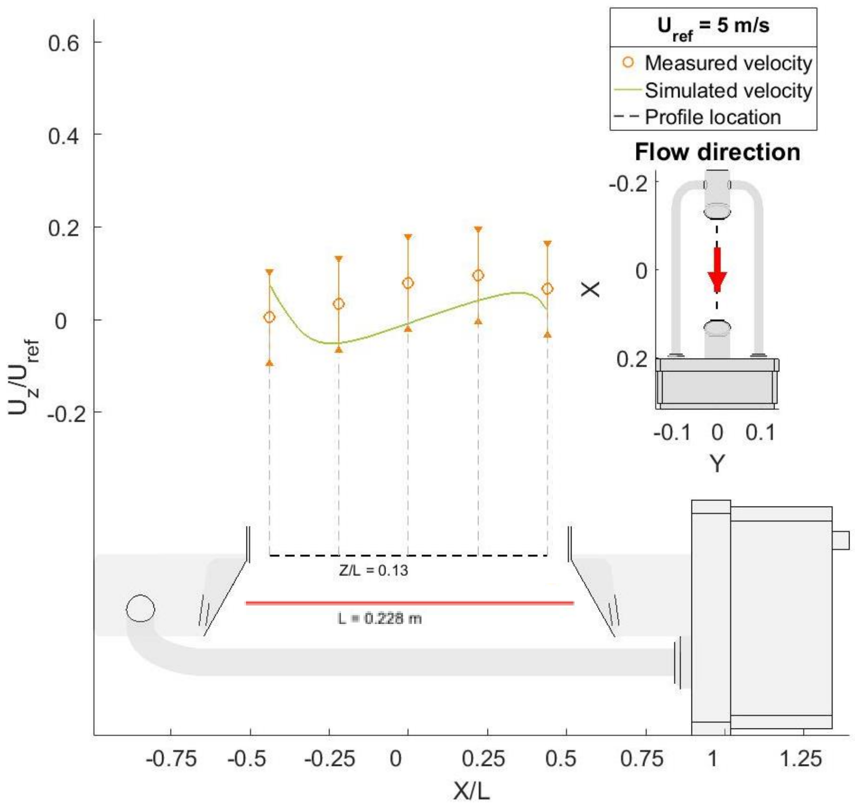




Validation of numerical simulation

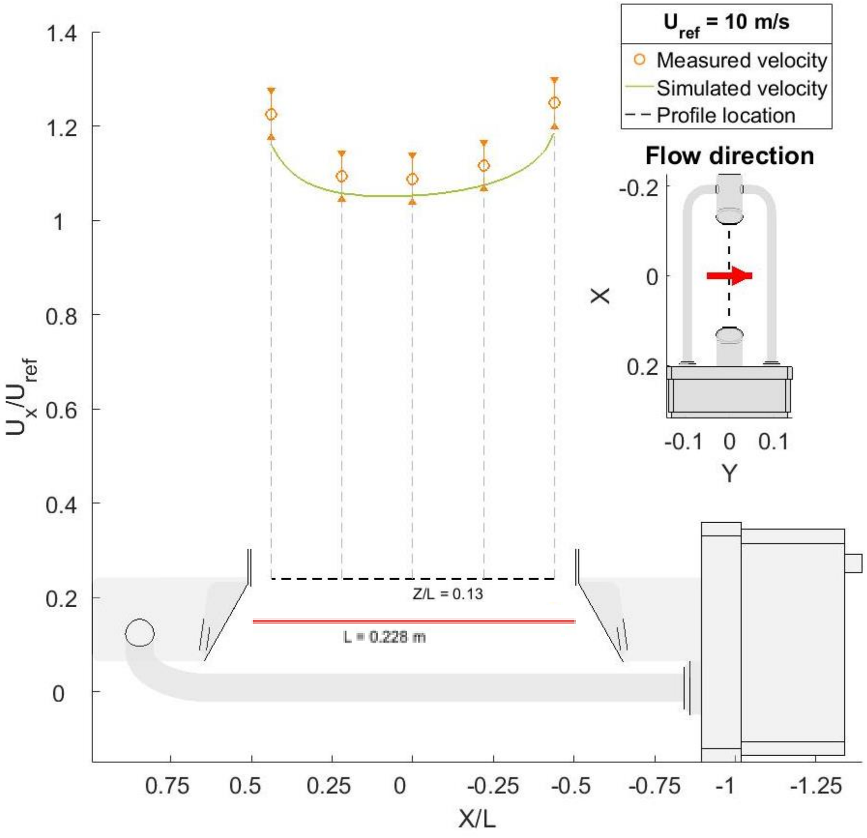
Comparison between cobra measurements and simulated velocity profiles: **Frontal flow**

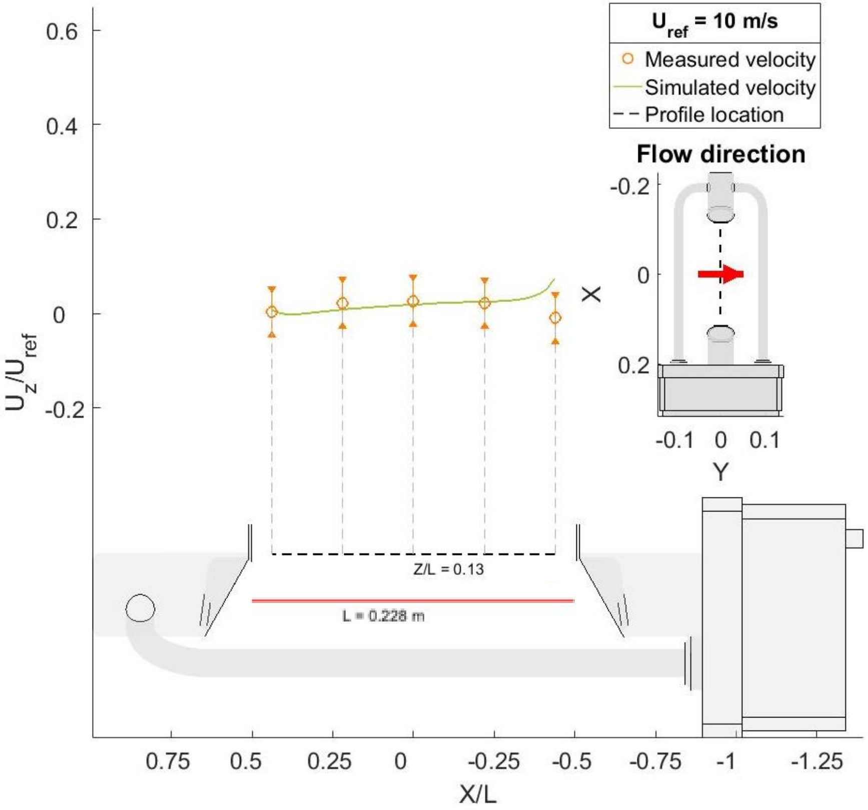




Validation of numerical simulation

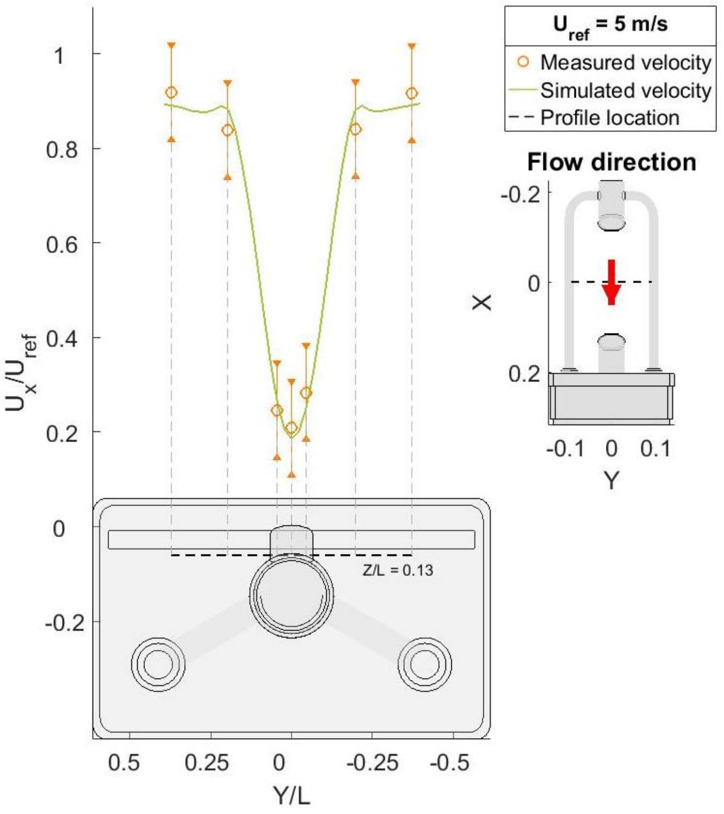
Comparison between cobra measurements and simulated velocity profiles: **Lateral flow**

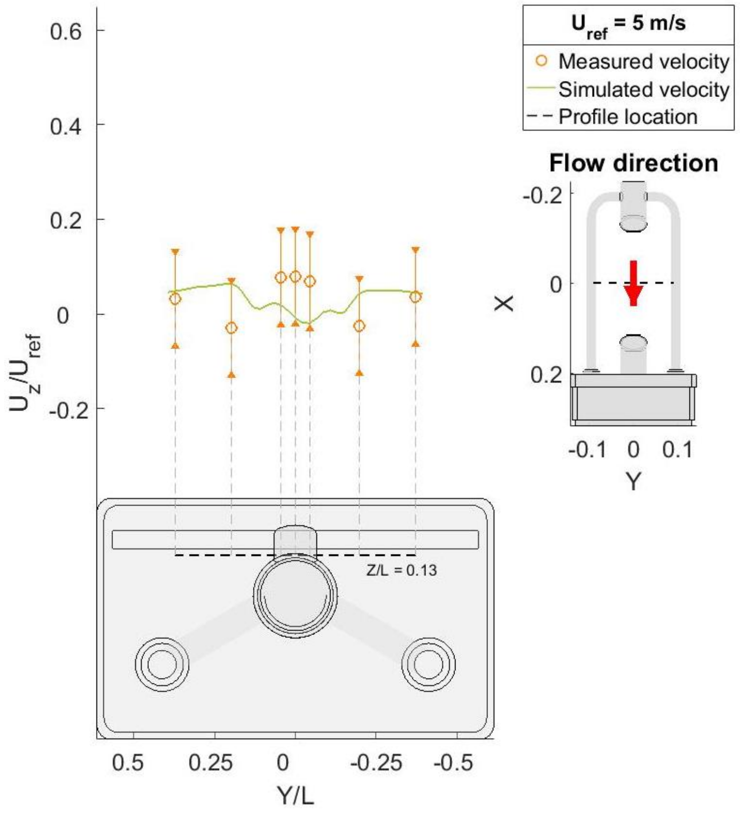




Validation of numerical simulation

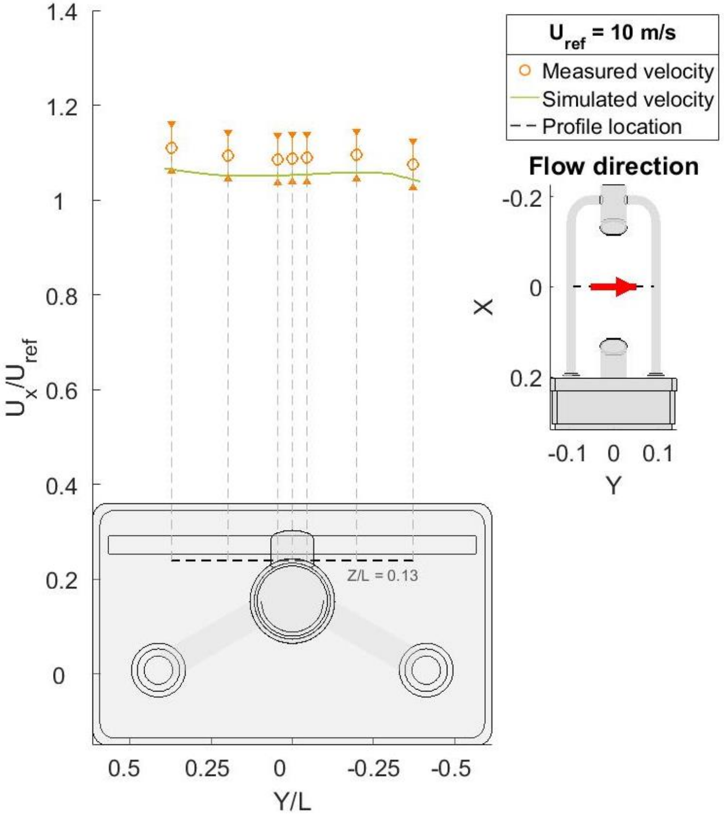
Comparison between cobra measurements and simulated velocity profiles: **Frontal flow**

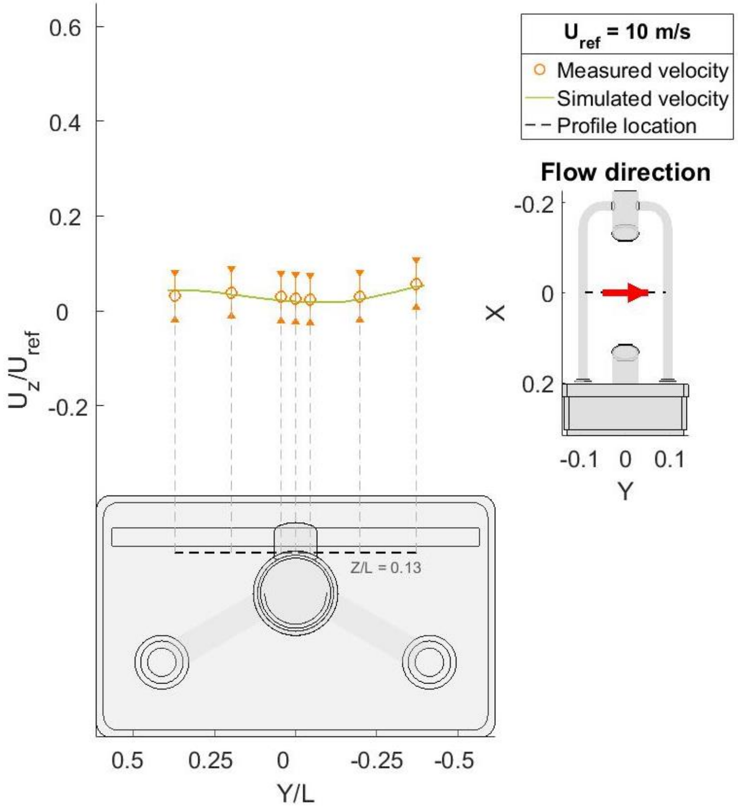




Validation of numerical simulation

Comparison between cobra measurements and simulated velocity profiles: <u>**Lateral flow**</u>





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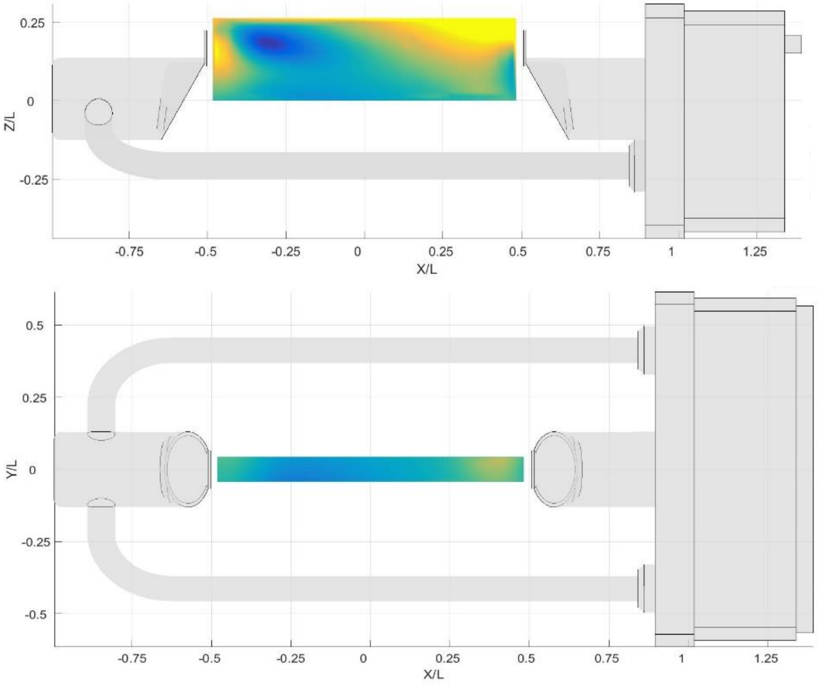
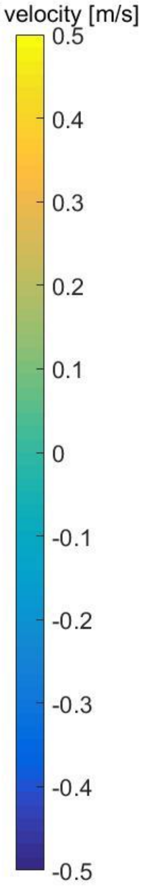
Numerical Simulations: flow field of velocity vertical component

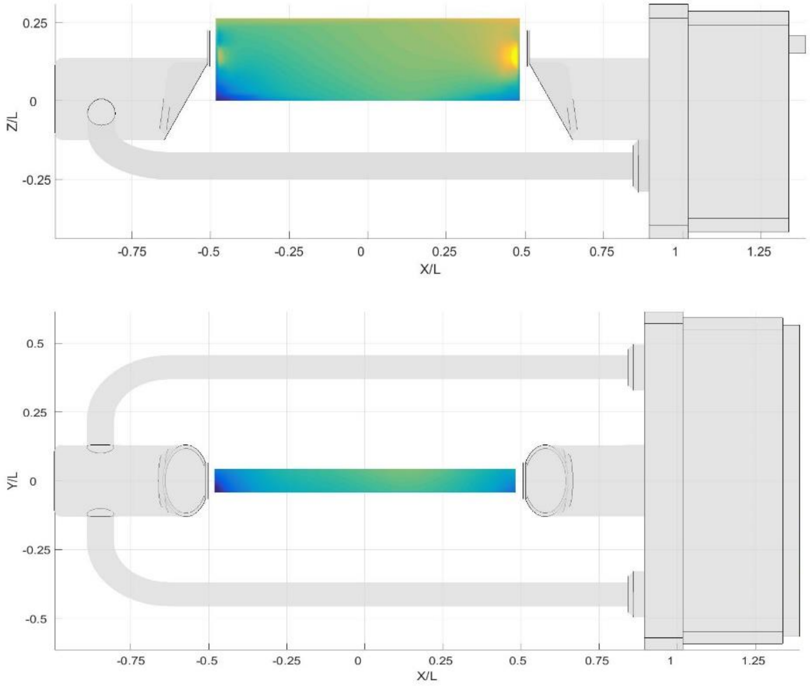
Velocity fields in proximity of the sensing area of the instrument: Vertical velocity

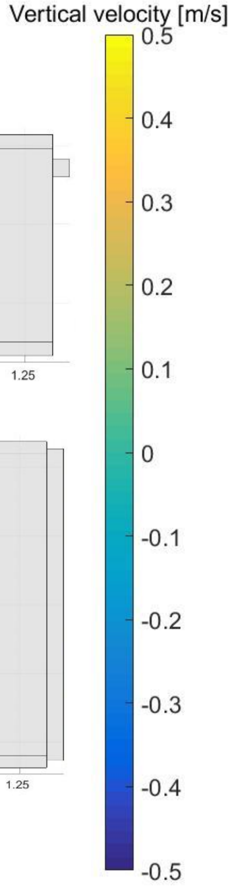
Frontal flow





Lateral flow





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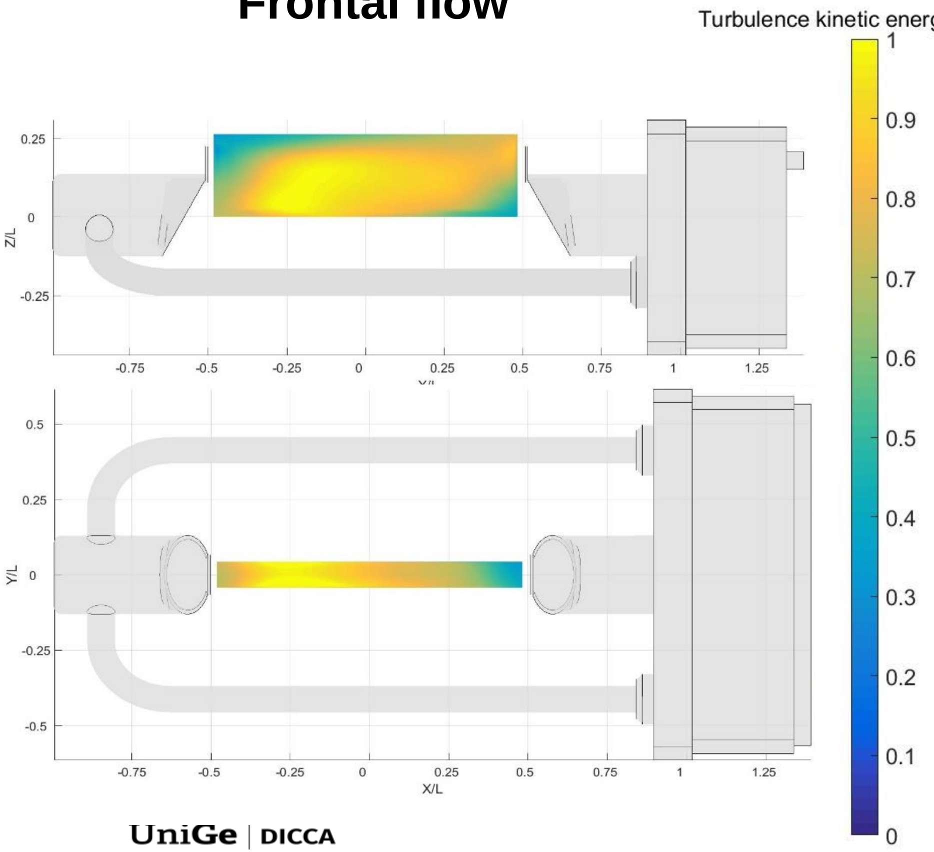
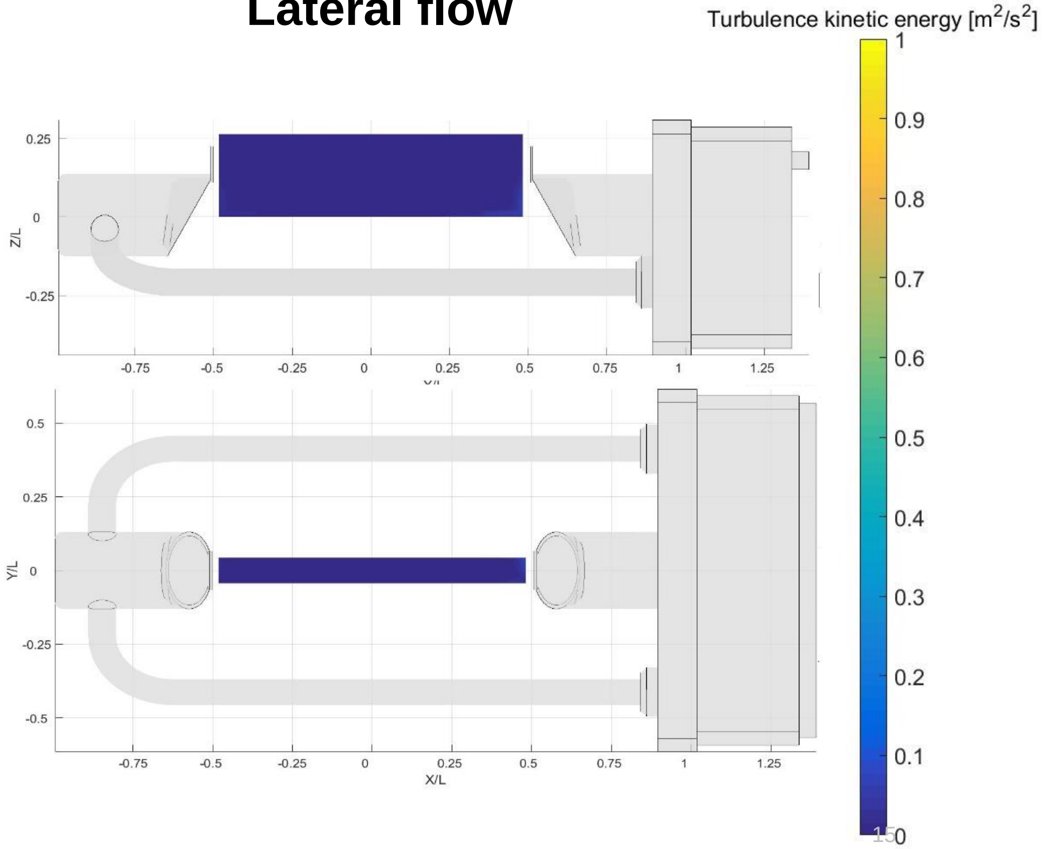
Numerical Simulations: turbulent kinetic energy

Turbulence kinetic energy fields in proximity of the sensing area of the instrument

Frontal flow



Lateral flow



Conclusions

In this work we focus on the bluff body aerodynamic response of theThies-LPM disdrometer.

Numerical simulations were performed by considering two wind velocities and directions.
Wind tunnel experiments were conducted to validate numerical results.

Results highlight that the complex shape of the gauge strongly affects the airflow patterns above and along the measuring area, and this influence depends on the wind direction.

Focusing on the measuring area of the gauge, comparisons between vertical velocity components and turbulent kinetic energy on an horizontal and central vertical sections, show that the less impacting configuration (with a lower impact on the measurement) is the one where the wind is normal-directed with respect to the longer gauge axis (lateral flow).

References

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