UrbaWind
Use of a CFD model for modeling the wind in urban area

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Abstract summary

Computational Fluid Dynamics (CFD) is already a necessary tool for modeling the wind over complex rural terrains. Meteodyn has developed *UrbaWind*, which is an automatic CFD software for computing the wind between buildings for small wind turbines as well as pedestrian comfort.

Compared to rural open spaces, the geometry in urban areas is more complex and unforeseeable. The effects created by the buildings make the modeling of urban flows more difficult. Some typical effects that we have to cope with in urban flows are:

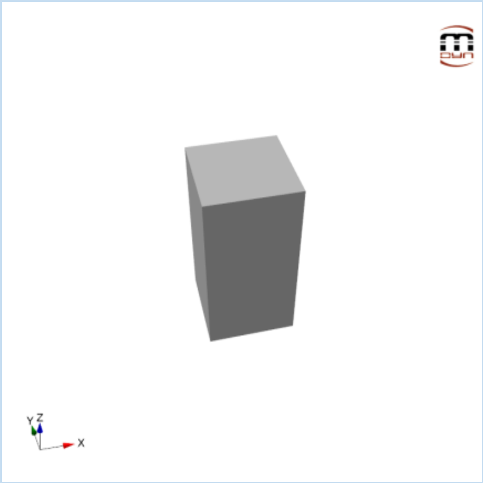
- Vortexes at the feet of the towers
- High wind speed near the edges of the upwind face
- Spiral deviation because of the oblique clearing of a bar
- Lateral wake effects behind a building
- High wind speeds in pedestrian ways under a building
- Venturi effect: high wind speeds at the narrowing of an angle open to the wind
- Wise effect: vortex amplified by a building, which is lower upstream

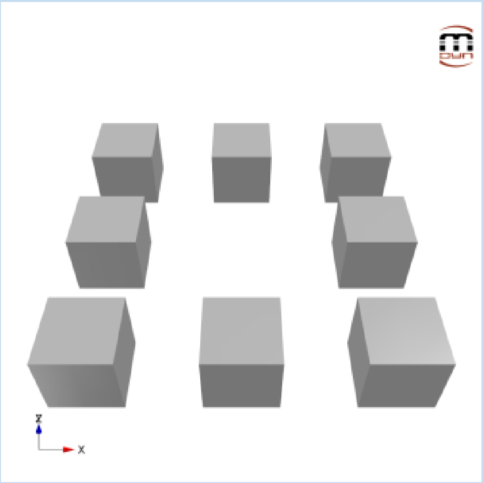
The model used in *UrbaWind* allows to take these effects into account in order to predict the wind characteristics with accuracy.

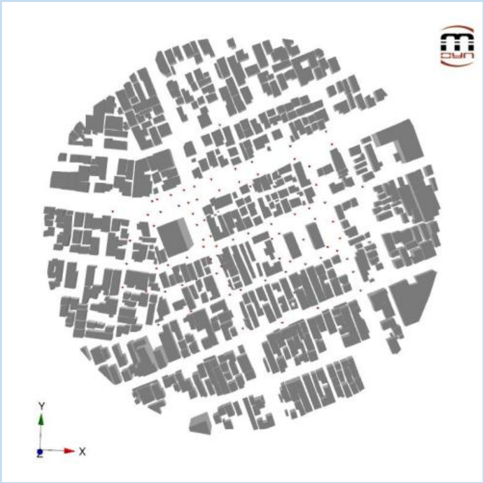
Objectives

In order to validate *UrbaWind*'s results, different study cases based on practical uses proposed by the *Architectural Institute of Japan* [1] have been set up. The three selected cases have an ascending complexity, from the simple block to the complete rebuilding of a quarter of the Japanese city of Niigata. These published cases allowed to compare the computations results of *UrbaWind* with the measurements of the *AIJ*.

Therefore, the sites have been recreated in a file format that can be used by *UrbaWind* and the conditions taken for the CFD computations are as near as possible of the experiments conditions. The values obtained by the computations are then compared with the measured values.







Methods

UrbaWind solves the equations of Fluid Mechanics, i.e. the averaged equations of mass and momentum conservations (Navier-Stokes equations). When the flow is steady and the fluid incompressible, those equations become:

$$\frac{\partial \rho \bar{u}_i}{\partial x_i} = 0 \tag{1}$$

$$-\frac{\partial \left(\rho \bar{u}_j \bar{u}_i \right)}{\partial x_j} - \frac{\partial \bar{P}}{\partial x_i} + \frac{\partial}{\partial x_j}\left[\mu \left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i} \right) - \rho \overline{u'_i u'_j} \right] + F_i = 0 \tag{2}$$

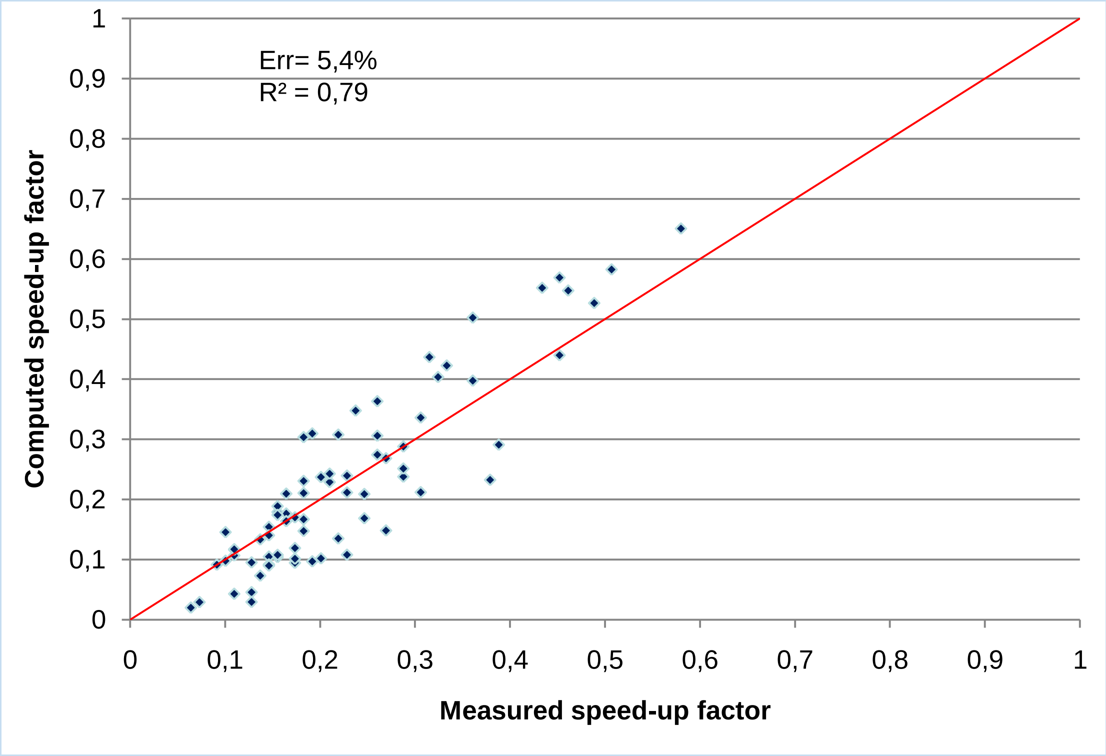
The turbulent fluxes are parameterized by using the so-called turbulent viscosity. This viscosity is considered as the product of a length scale by a speed scale which are both characteristic lengths of the turbulent fluctuations. The generation of the boundary conditions is automatic for the user. The vertical profile of the mean wind speed at the computation domain inlet is given by the logarithmic law in the surface layer, and by the Ekman function [2]. A 'Blasius'-type ground law is implemented to model frictions (velocity components and turbulent kinetic energy) at the surfaces (ground and buildings)

The non-structured solver *MIGAL-UNS* which has been regularly used for some years now, and has already been fully validated [3] on number of academic cases is used in UrbaWind. It is a fast and robust coupled multi-grid algebraic solver which allows a complete resolution of 3D equations for fluid mechanics (RANS method).

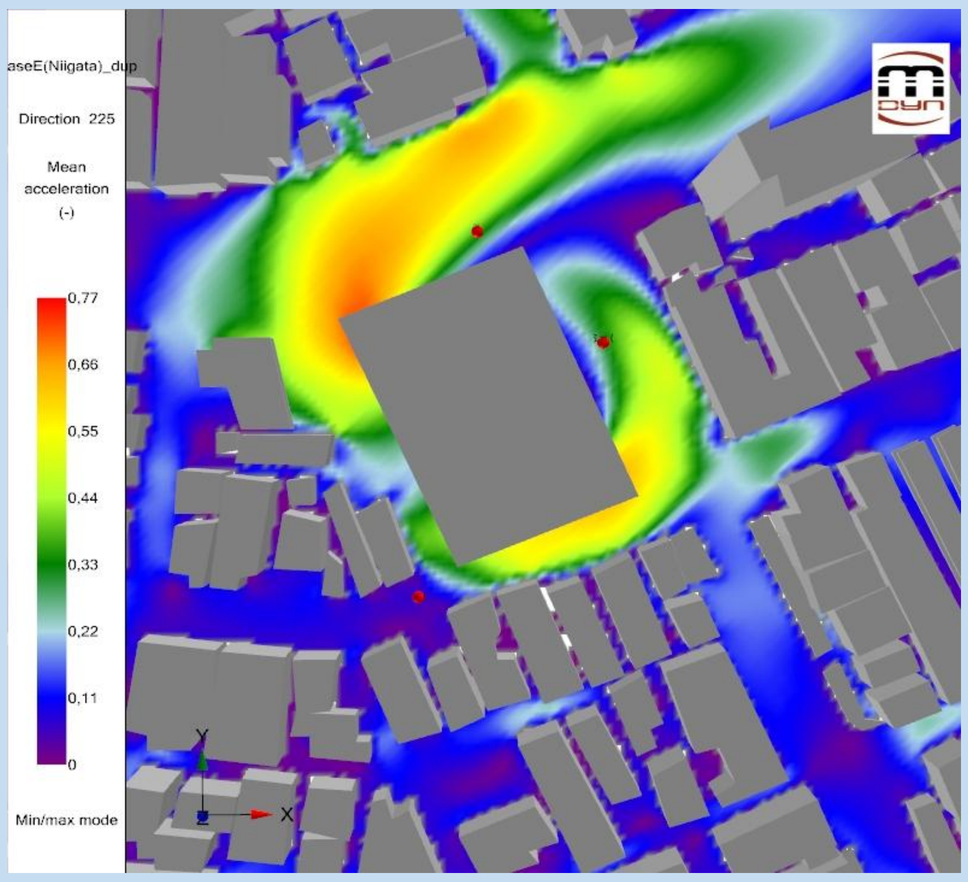
At last, the mesh is automatically generated with refinements at key areas of the domain. In our case studies, we choose for the refinement an horizontal resolution of 50cm and 20 cm for the vertical resolution.

Results

The speed-up factors of the computation have been compared to the speed-up factors obtained by the experimental measurements. While the measurements for the cases 1 (simple block) and 2 (group of blocks) have been done in wind tunnels, the measurements of the case 3 (city of Niigata) have been carried out on-site [1]. In the following graph, we have represented the computed values functions of the measured values for the case 3.



The error and the determination coefficient allow validating the results of *Urba*Wind. Indeed the mean error is lower than 5,4%. And 90% of the points have an error value lower than 12%. Nevertheless, we note that the worst points correspond to the very low-speed points where a small variation of the absolute value gives a high error.



Finally, the table hereunder shows that the results provided by UrbaWind are much closed to the results of the experimental measurements of the Architectural Institute of Japan. Indeed the typical error of the computations is at most 5,8% and even decreases to 4,9% in the first case.

	Error	R²
1/ One block, Z=1,25m	4,9%	0,93
2/ Group of blocks	5,8%	0,71
3/ Quarter of Niigata	5,4%	0,79

Conclusions

To conclude, this study allows validating the software *Urba*Wind as well for theoretical cases (first and second cases) as for real cases (quarter of Niigata) by offering a minor error margin. In several precise cases of particular interest areas (top of a building, backside of a building) and for low speeds, METEODYN recommend the use of a given LES (Large Eddy Simulation) model on which our company have a recognized expertise.

All the wind characteristics such as wind speed, turbulence, wind shear or vertical wind can be computed at the wondered height. Those are critical information for calculating fatigue problems and extreme loads on a turbine.

References

[1] Architectural Institute of Japan, 2008, *Guidebook for Practical Applications of CFD to Pedestrian Wind Environment around Buildings*. (http://www.aij.or.jp/jpn/publish/cfdguide/index_e.htm)
[2] Garratt J.R., 1992, *The atmospheric boundary layer*, Cambridge Atmospheric and space sciences series.
[3] Ferry M., 2002, *New features of the MIGAL solver*, Proc. Of the Phoenics Users Int. Conf., Moscow, Sept. 2002

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