

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. 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:

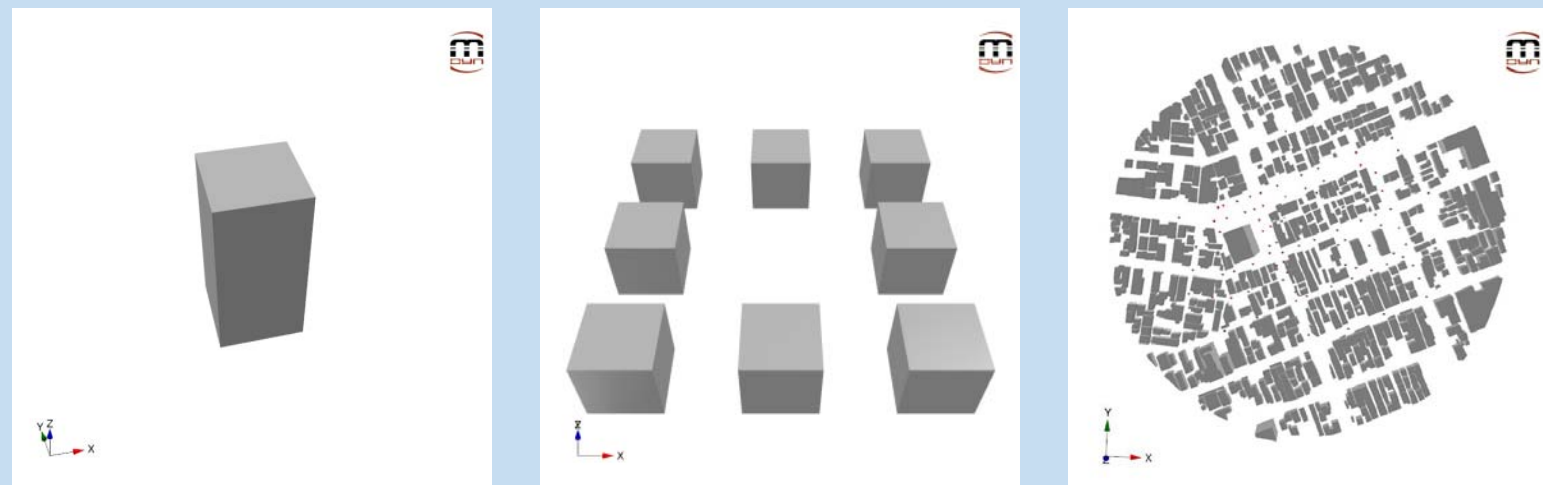
- Vortexes at the feet of towers
- High wind speeds near the edges of upwind faces
- Spiral deviation because of the oblique clearing of a bar
- Lateral wake effects behind buildings
- High wind speeds in pedestrian ways under buildings
- Venturi effect: high wind speeds at the narrow end of an angle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

The model used in *UrbaWind* takes all these effects into account to accurately predict wind characteristics.

Objectives

In order to validate *UrbaWind's* results, several case studies were proposed by the *Architectural Institute of Japan* [1]. The cases having already been published it was possible to compare the computation results of *UrbaWind* with the actual measurements of the *AIJ*. The three cases have an ascending complexity, from the simple block to the complete rebuilding of a quarter of the Japanese city of Niigata.

The sites were recreated in a file format usable by *UrbaWind* and the conditions taken for the CFD computations were set as near as possible to the experimental conditions.



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:

$$(1) \quad \frac{\partial \rho \bar{u}_i}{\partial x_i} = 0$$

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

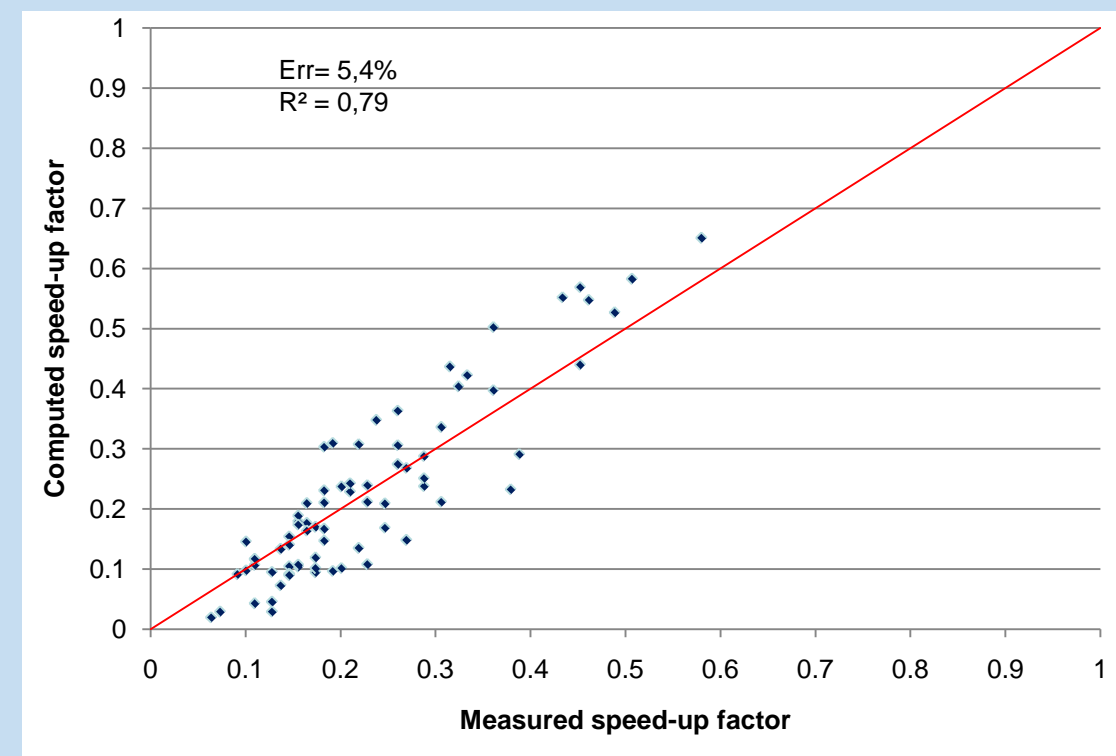
The turbulent fluxes are parameterized by using the so-called turbulent viscosity. This viscosity is considered as the product of a length scale by a speed scale which are both characteristic lengths of the turbulent fluctuations. Boundary conditions are automatically generated. The vertical profile 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)

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

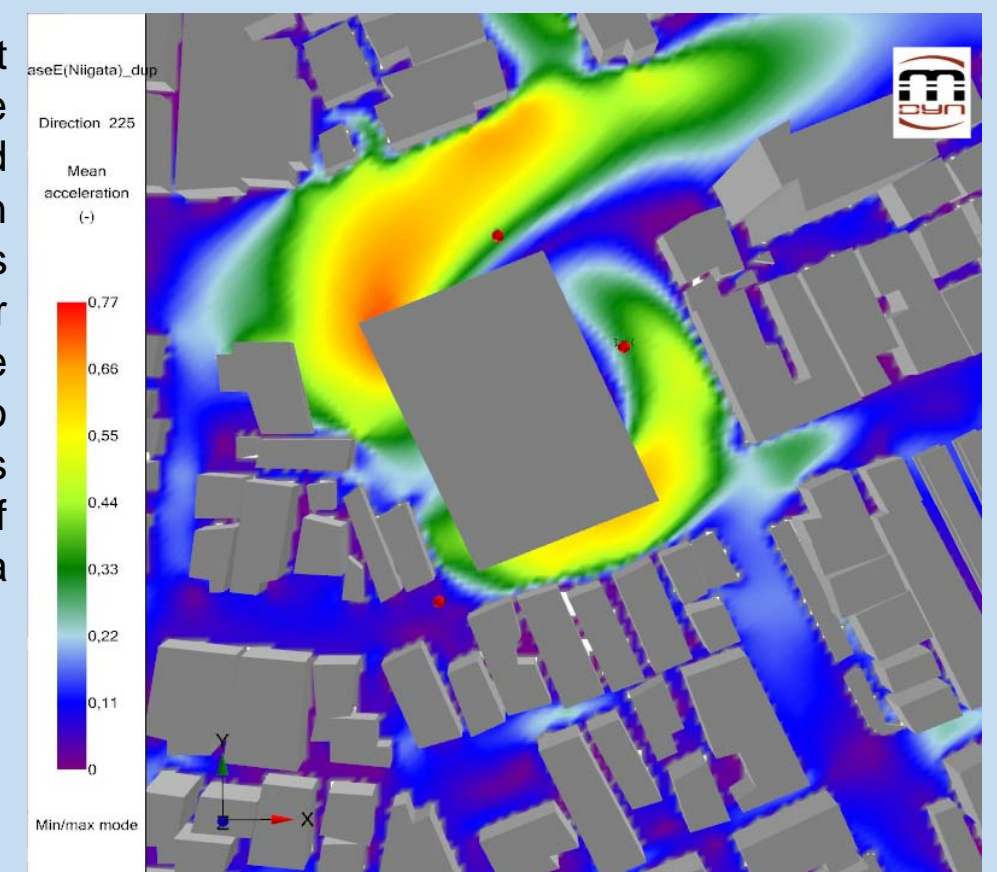
Finally, the mesh is automatically generated with refinements at key areas of the domain. In our case studies, we choose for the refinement an horizontal resolution of 50cm and 20 cm for the vertical resolution.

Results

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



The error and the coefficient of determination validate the results of *UrbaWind*. Indeed the mean error is lower than 5,4%. And 90% of the points have an error value lower than 12%. What's more, 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 below shows that the results provided by *UrbaWind* are very close 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	R ²
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 validates the software *UrbaWind* for theoretical cases (first and second cases) and 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 recommends the use of a given LES (Large Eddy Simulation) model on which our company has a recognized expertise.

All the wind characteristics such as wind speeds, turbulence, wind shear or vertical wind can be computed at the desired height. This information is critical for calculating fatigue problems and extreme loads on turbines.

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 Phoenix Users Int. Conf., Moscow, Sept. 2002