

MODELLING OF WIND COMFORT FOR PEDESTRIANS IN URBAN OUTDOOR SPACES

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Background

The study of pedestrian aerodynamic comfort in urban outdoor spaces is crucial for urban planning and enhancing residents' well-being. Accurate wind prediction helps ensure safety and comfort, especially in windy areas.

The 3D diagnostic flow model PSWIFT is used to study the complex interactions between wind and the built environment. PSWIFT is developed in collaboration between SUEZ Aria Technologies and the CEA. Simulations are performed from the mesoscale to the microscale, where buildings are explicitly represented (Tinarelli et al., 2013; Armand et al., 2021). PSWIFT can handle huge urban areas thanks to highly efficient parallelization (Oldrini et al., 2019; 2021). It delivers near-CFD accuracy with computation times reduced by several orders of magnitude. PSWIFT model's significant improvements have been extensively validated, and partly presented at HARMO conference (Ribstein et al., 2024, 2025).

Method

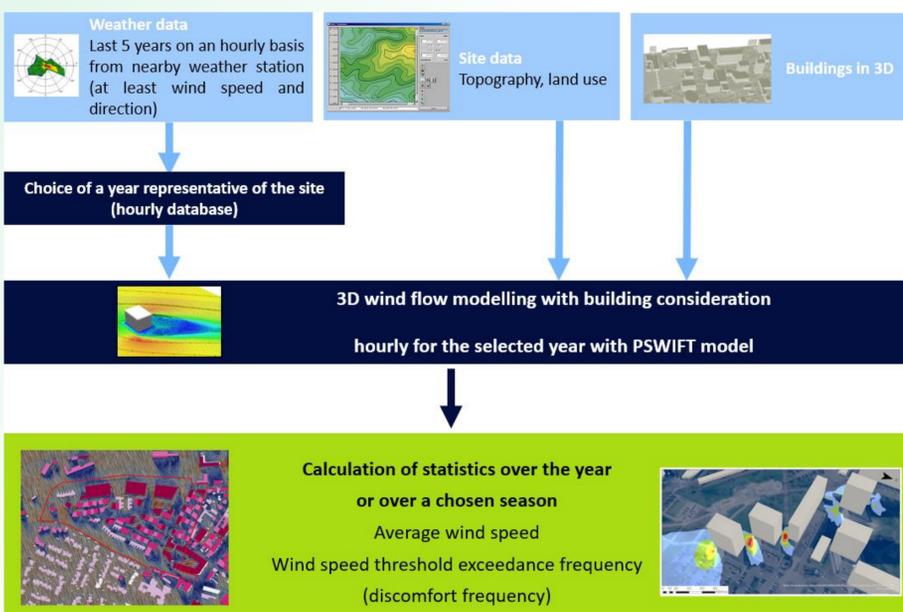
The wind comfort criterion used is based on the 3.6 m/s threshold (Delpech et al., 2005) defined by the Centre Scientifique et Technique du Bâtiment (CSTB). It characterizes an upper limit of comfort for pedestrian stationary activity.

The methodology consists in simulating wind flow in 3D with PSWIFT over the study area over a long period, e.g. hourly for a year. Statistics on wind fields computed by PSWIFT are then produced, which would be cost-prohibitive with a full CFD model. Choosing PSWIFT offers two major advantages:

- a short CPU time;
- a straightforward integration of on-site data (weather, topography, land use and buildings) through the GIS-embedded AirAdvanced® Map desktop software.

To correctly assess the feeling of (dis)comfort, the wind discomfort frequency is computed and analysed. It corresponds to the percentage of time during which the comfort threshold of 3.6 m/s is exceeded during the study period while considering the activities practiced in the study area.

Implementation



Wind rose analysis shows prevailing directions from the southwest and northeast, causing more comfort threshold exceedances in streets aligned with this axis. While ~62% of winds measured at 10 m at the weather station exceed 3 m/s, PSWIFT results reveal much lower speeds at ground level, especially in open areas.

Modelling quantifies wind discomfort, while maps make results accessible to all stakeholders, even non-experts. In the study case, the new buildings cause additional discomfort of more than 20% in certain narrow streets compared to the initial situation. This supports tailored recommendations on building design and outdoor space use, enabling planners to make informed decisions and effectively communicate them to the public.

Limitations

Wind discomfort may be slightly overestimated because:

- Trees, which impede wind flow and thus enhance pedestrian comfort at street level, are not considered by PSWIFT.
- PSWIFT does not explicitly model the neighbourhood's overall aerodynamic drag due to CPU constraints, which would require incorporating momentum equations (Oldrini et al., 2014) and limit long-term statistics. Results reflect only the cumulative impact of individual buildings.

Conclusion

The PSWIFT model effectively assesses pedestrian wind comfort by delivering high-resolution 3D simulations over long periods with low computation time and straightforward integration of input data. Using discomfort frequency metrics, the method accurately identifies critical zones, guiding targeted urban design improvements. Despite minor limitations that may overestimate discomfort, it is a robust and practical tool for anticipating urban project impacts on pedestrian comfort.



Pedestrians at street level struggle with wind during a storm in Tokyo, Japan (Oke et al., 2017 - Credit: Y. Tsuno / AFP / Getty Images; with permission)

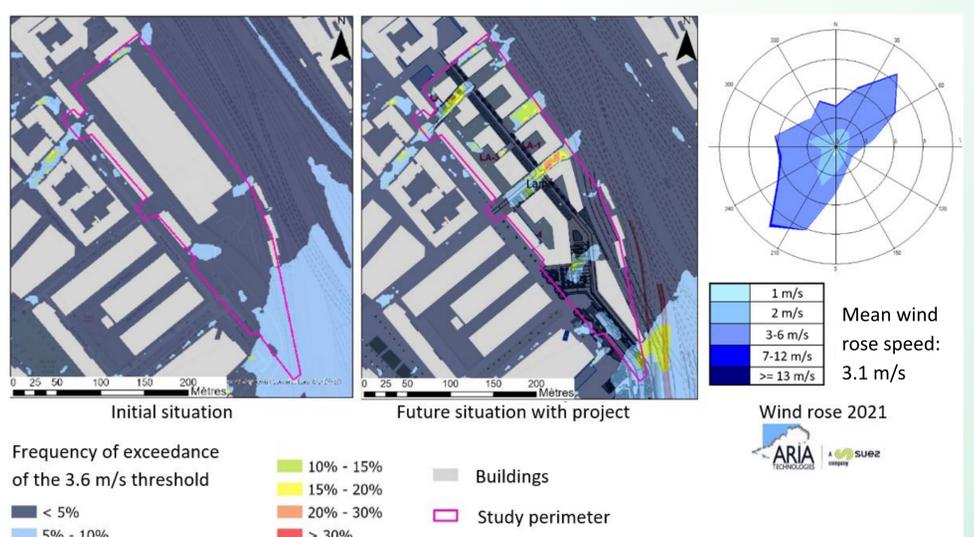
Activities	Examples	Maximum discomfort frequencies (as a percentage of annual time)
Prolonged stationary activity	Café terrace, open-air theatre, swimming pool	A few percent
Short-term stationary activity	Public garden, playground, shopping street	5%
Normal walking	Walkway, pedestrian crossing, building entrance	10%
Fast walking or outdoor sport practice	Car park, sidewalk of avenues, belvedere	20%

Maximum discomfort frequencies according to activities (Faure et al., 2009)

Study case

Let's consider an urban renewal project in a major European capital, involving the demolition and construction of new housing. The aim is to highlight the project's impact on the wind comfort of future users of outdoor spaces.

A 1x1 km area is modelled using 2021 weather data from a nearby station. Buildings are modelled according to their volume, with 3 m horizontal resolution. With PSWIFT, between 15 and 20 vertical levels are generally defined, rising up to ~200 m, with finer mesh near the ground to capture wind gradients. **PSWIFT simulates one year of hourly weather data in under 2 hours using 24 processors.**



Discomfort frequency before and after the housing construction project

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