ARCHIWIND

Microclimate Wind Assessment

B1 - modified

Pedestrian Wind Study including comfort and safety analysis. Mitigation strategy proposal for optimal usage.

For permissions or inquiries, please contact:

info@nablaflow.io

Overview

Simulation setup

Coordinates (WGS84 EPSG:4326)	Latitude: 53.465888752052024 Longitude: -2.2358060465879412
Nearest city center	Manchester, England, United Kingdom (~2 km from city center reference)
Report generation date	October 01, 2026
ArchiWind version	v1
Wind comfort standard	Lawson 2001 (user-selected)
Historical wind data source	ArchiWind standard (MeteoBlue API, last five years of historical data) (user-selected)
Analysis area	900 m diameter
CFD mesh size	13.2 million cells

Model & climate assumptions

Project center coordinates	Latitude: 53.465888752052024 Longitude: -2.2358060465879412
Tallest structure height (bounding box vertical extents)	66.7 m
Building of interest height (bounding box vertical extents)	57.5 m
Simulation domain ceiling height	333.6 m
Meteorological reference height	10 m
Upstream probe-set height above local ground	—
Test surface A height	1.5 m
Test surface A mesh cell size (building patch, min / avg)	min: 0.05 m, avg: 0.27 m

Historical wind data overview

Metric	Year	Summer	Winter
Average reference wind speed (10 m)	4 m/s	3.7 m/s	4.4 m/s
Most frequent wind directions	270°(W): 11% 292°(WNW): 10% 180°(S): 9%	292°(WNW): 12% 270°(W): 12% 225°(SW): 9%	180°(S): 11% 202°(SSW): 10% 270°(W): 10%

Key findings in control area from simulations

Control area: auto-detected building(s) radius ≈ **71 m**, added analysis buffer ≈ **100 m**, total analysis radius ≈ **171 m** measured from the building center.

Metric	Summer	Winter
Share within high-comfort classes (Sitting and Standing)	94%	84%
Share possibly requiring mitigation (Business walking and Uncomfortable)	0%	3%

Executive summary

This wind analysis, **B1 - modified**, was carried out through NablaFlow's online platform ArchiWind. The workflow combines historical wind statistics, Computational Fluid Dynamics (CFD) simulations around the project geometry, and the **Lawson 2001** activity-based comfort scheme. Comfort classes range from **Sitting** to **Uncomfortable**.

Summer: main wind direction **292° (WNW) - 11.9%**. **94%** of the control area stays within the two best wind comfort classes (**Sitting and Standing**); **0%** falls in the least comfortable classes (**Business walking and Uncomfortable**).

Winter: main wind direction **180° (S) - 11.4%**. **84%** of the control area stays within the two best wind comfort classes (**Sitting and Standing**); **3%** falls in the least comfortable classes (**Business walking and Uncomfortable**).

Always compare the reported comfort class with the intended activity. If an area is classified as **Business walking** but must support a more comfortable class, plan targeted shielding (vegetation, low walls, or screens) against the dominant exposures indicated above.

Wind climate and intended activities vary between summer and winter, so review the seasonal comfort metrics side by side to judge suitability and mitigation needs across the report.

ArchiWind automatically targets only **Business walking and Uncomfortable** when proposing mitigation, yet even "better" classes may be too windy for the intended use—study the detailed CFD results and, if needed, inspect the flow with the particle animation in the interactive webpage to design shielding that slows or redirects the wind.

The effect of any mitigation concept can be estimated by running another ArchiWind simulation where the proposed shielding or geometry adjustments are included.

Scan this QR code to open the interactive ArchiWind results page (access until **October 01, 2027**, provided that the simulation owner has an active license).
If the simulation is not public, the ArchiWind project owner already has access through their account.
If it is password-protected, ask the owner for the required password.

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Introduction

Thank you for using ArchiWind from NablaFlow. ArchiWind is an automated wind analysis tool for larger construction projects. Our goal is to provide reliable and detailed wind simulations quickly and easily for your project.

The automated process and user-friendly interface make advanced wind simulations, which were previously time-consuming and expertise-dependent, more accessible for architects, urban planners, and building engineers. ArchiWind can be used as part of the planning phase or as a basis for public approval of a construction project.

The models and methodology used are developed through several years of research and development and are based on best practices in the field.

Disclaimer

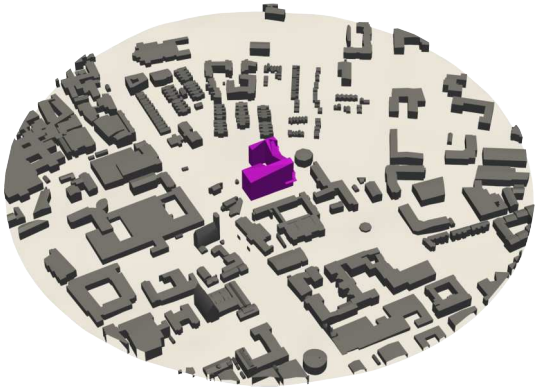
ArchiWind follows best practices for CFD simulations of atmospheric wind in urban environments. We are continuously working on developing and improving models and processes to ensure accurate and reliable results. However, simulations of physical processes will always involve uncertainty related to modeling, discretization, and numerical solution methods.

The analysis is based on average wind field values and does not consider extreme values and gusts.

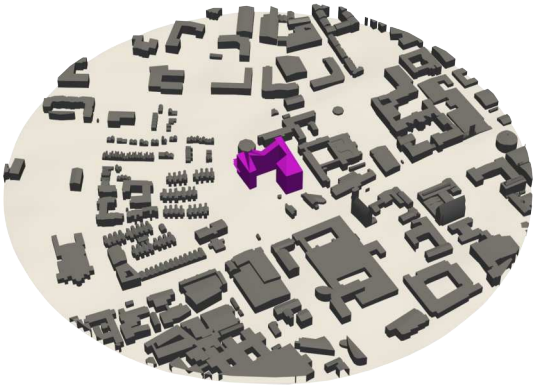
NablaFlow is not responsible for the incorrect interpretation and use of data included in this report.

Site description

The wind analysis is based on the geometry models of new buildings, terrain and surrounding buildings shown in figure 1.



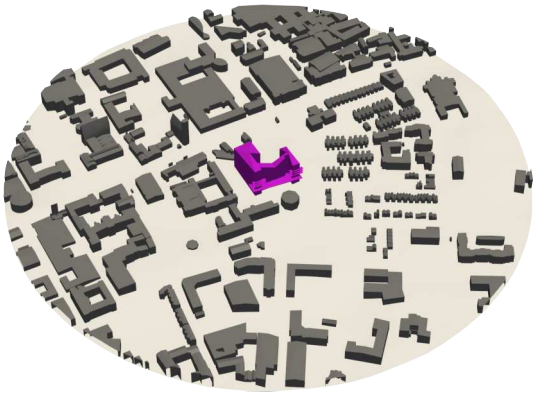
(a) view from north



(b) view from east



(c) view from south



(d) view from west

Figure 1: Overview of project site

Methods

Pedestrian wind comfort and safety

Pedestrian Wind Comfort (PWC) and Pedestrian Wind Safety (PWS) are important aspects of urban planning and design, as they directly affect the livability and usability of outdoor spaces. High wind speeds can cause discomfort, reduce the attractiveness of public areas, and in extreme cases pose safety risks. In simple terms, wind comfort deals with everyday nuisance winds, while wind safety concerns rare but dangerous strong winds.

Assessing PWC and PWS involves detailed numerical simulation of local wind conditions using Computational Fluid Dynamics (CFD), combined with regional wind climate data to evaluate comfort and safety according to established criteria. In this analysis, **16** wind directions are used to represent the main flow conditions. The resulting local wind speeds are then statistically combined with the regional climate data to estimate how often certain threshold values are exceeded at pedestrian level. The results are evaluated at a height of 1.5 meters above the ground or building rooftops and presented as a color-coded map showing how wind comfort and safety vary across the study area.

Criteria for wind comfort

There are several ways to evaluate wind comfort (Blocken & Carmeliet, 2004). The chosen method is based on the **Lawson 2001 (Updated Lawson)** wind comfort criteria proposed by Lawson (1978), summarized in Table 1.

The **Lawson 2001** update keeps the 5 % exceedance criterion but shifts the thresholds to reflect typical use of modern public spaces: 4 m/s for sitting areas, 6 m/s for standing, 8 m/s for strolling, and 10 m/s for business walking. Locations where 10 m/s is exceeded more than 5 % of the time are deemed uncomfortable for regular pedestrian use.

Table 1: Table 1. Lawson 2001 Comfort Categories.

Category	Wind speed	Frequency	Color code
Sitting	≤ 4 m/s	≤ 5%	
Standing	≤ 6 m/s	≤ 5%	
Strolling	≤ 8 m/s	≤ 5%	
Business walking	≤ 10 m/s	≤ 5%	
Uncomfortable	> 10 m/s	> 5%	

Criteria for wind safety

Wind safety is assessed with the Dutch standard NEN 8100 (Nederlands Normalisatie-instituut, 2006) and focuses on how often 15 m/s mean wind speeds are exceeded 2 m above ground. Local accelerations around corners, through narrow passages, or downwash from tall buildings can create very high wind speeds for specific wind directions. Areas are considered safe when the threshold is exceeded less than 0.05% of the time (about 4.4 hours/year) and dangerous when it is exceeded more than 0.30% of the time (about 26 hours/year); values in between indicate a limited risk that may call for mitigation. The standard does not explicitly capture combinations of high mean winds and strong turbulence, so judgement is still required where powerful gusts are expected. The criteria used in this report are summarized in Table 2.

Table 2: Wind safety criteria and color coding (NEN 8100).

Category	Wind speed	Frequency	Color code
No risk	> 15 m/s	≤ 0.05%	
Limited risk	> 15 m/s	0.05% - 0.30%	
Dangerous	> 15 m/s	> 0.30%	

Wind simulations

Buildings and other structures can significantly affect the wind field. Therefore, to evaluate wind comfort at a detailed level, it is necessary to know the local wind speed at any point in the specific area.

Numerical simulation models, also known as CFD (Computational Fluid Dynamics), are used to find the local wind speed. In these models, the area is divided into a network of cells. Equations are set up for each cell based on physical laws of pressure and velocity, which are then solved using numerical methods. In this study, around 13.2 million cells were used. A section of the model showing the partitioning is shown in figure 2.

The frequencies of local wind speed must be calculated to draw the comfort map. This is done for each wind distribution and all wind directions, a total of 16 wind directions. Since the wind pattern is similar regardless of wind speed, one simulation is made per wind direction. The simulations are run with a reference wind speed of 5.0 m/s. The wind field is then scaled to find local wind speeds for the individual categories. These are combined with wind statistics for the area to find the total frequency of local wind speeds. As explained in the previous section, these frequencies are used to create the comfort map. The methodology used in this analysis has been developed over several years and is described in detail by Hågbo, Giljarhus, and Hjertager (2021) and the subsequent Building and Environment publication (Hågbo et al., 2024).

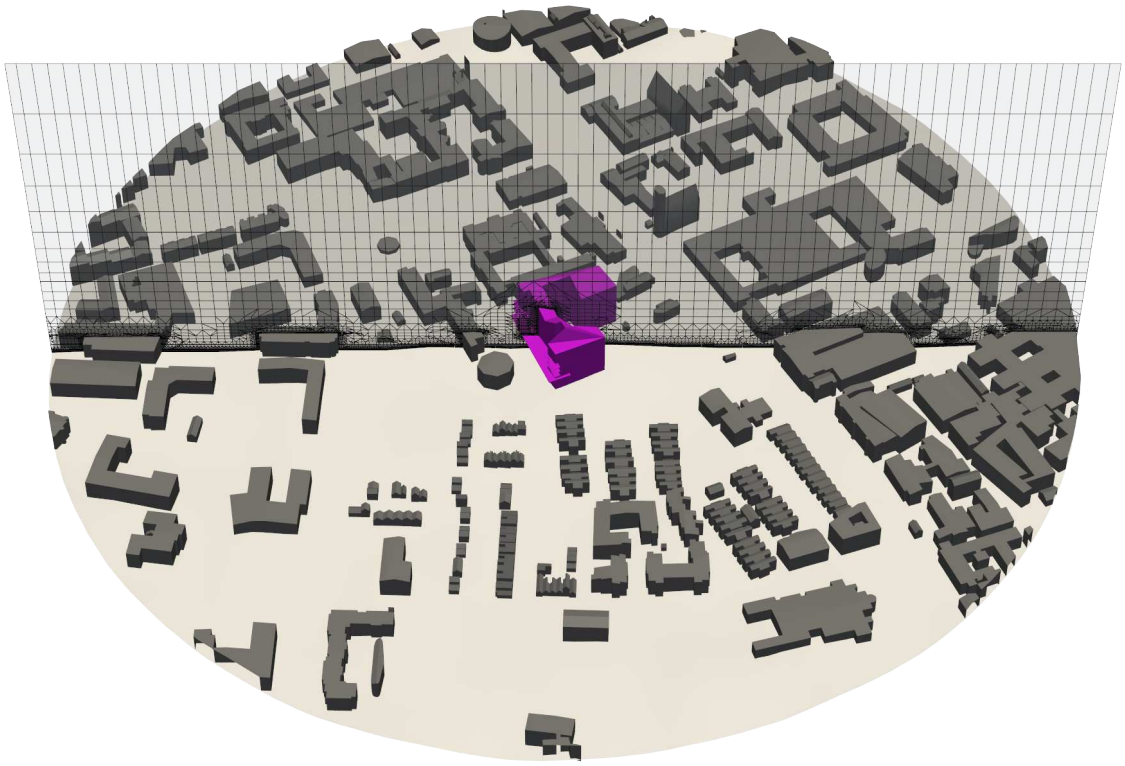


Figure 2: Illustration of calculation cells in the simulation model.

Wind statistics

Wind data for the area is retrieved from the meteoblue ERA5T historical weather service, which serves ECMWF's near real-time ERA5 (ERA5T) reanalysis together with meteoblue's post-processing pipeline to provide hourly wind statistics for the site (meteoblue, 2024; ECMWF, 2022).

This analysis assesses wind from 16 different directions. Figure 3 shows wind roses for the area, both the annual distribution and seasonal variations for summer and winter. The wind roses show the frequency of different wind directions and speeds, indicating which wind directions are most emphasized in the analysis. The dominant wind directions on an annual basis are from west, west-northwest and south. In summer, the wind most often comes from west-northwest, west and southwest, and in winter from south, south-southwest and west. The strongest winds come from west, southwest and west-southwest in the summer and west, west-southwest and south-southwest in the winter.

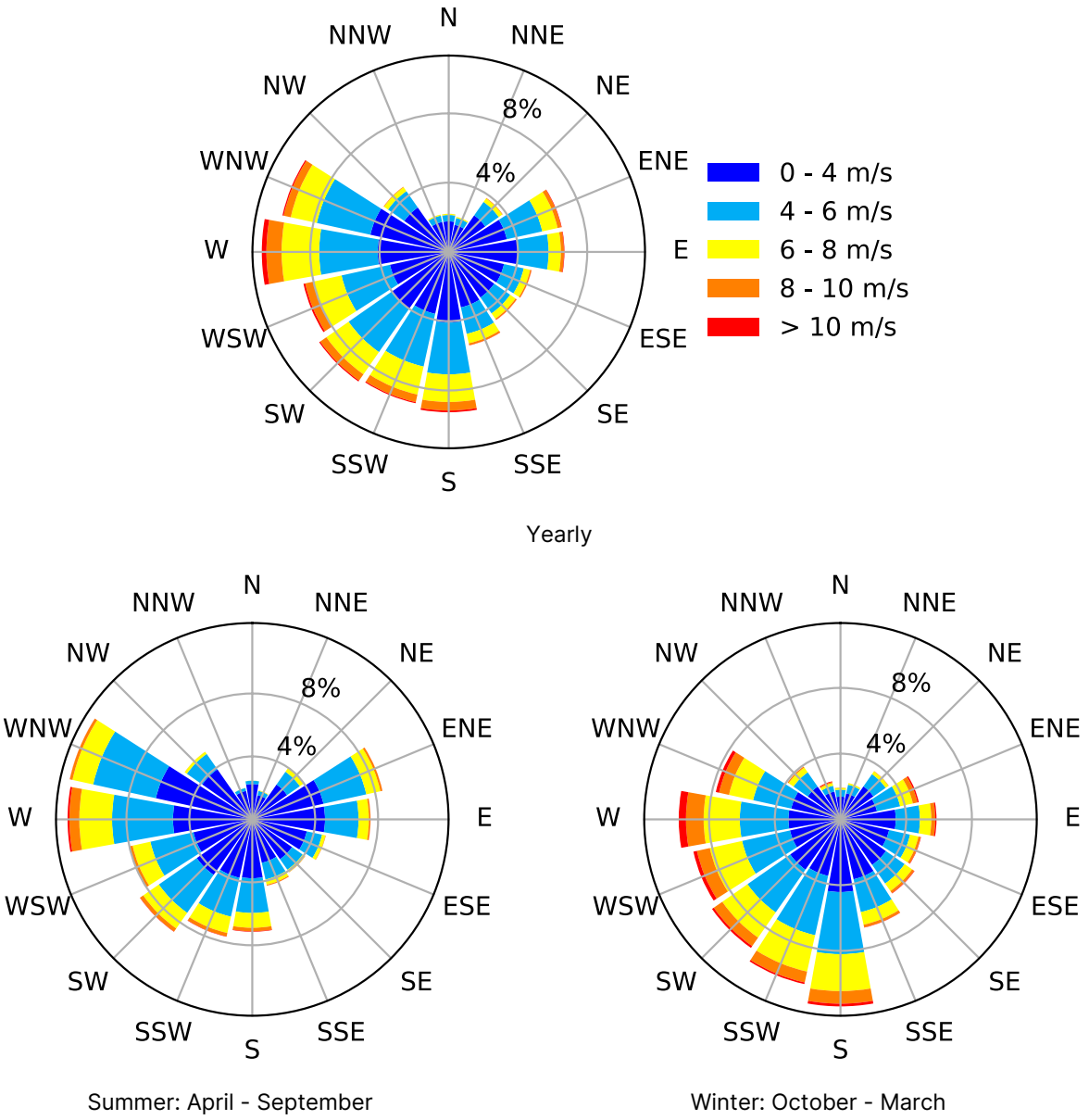


Figure 3: Wind rose showing wind statistics for the location at 10 meters height above ground. Data from the

meteoblue ERA5T historical weather service (meteoblue, 2024; ECMWF, 2022).

Boundary conditions

In meteorology, wind speed is commonly referenced at 10 meters above ground. The inlet profiles for these simulations assume a neutrally stable atmospheric surface layer and follow a logarithmic relationship between altitude and wind speed.

Upstream surface roughness controls how rapidly the wind slows down near the ground. ArchiWind derives this roughness from ESA's WorldCover 2021 dataset (ESA, 2023), which classifies land cover globally on a 10-meter grid. Each class is mapped to a characteristic roughness length using an empirical lookup table; water bodies rely on the Hersbach (2010) formulation based on mean wind speed. For every wind direction we evaluate the land cover inside a sector that extends 500 m upstream of the simulation domain (Figure 4), and the median roughness in that sector defines the inlet profile for that direction.

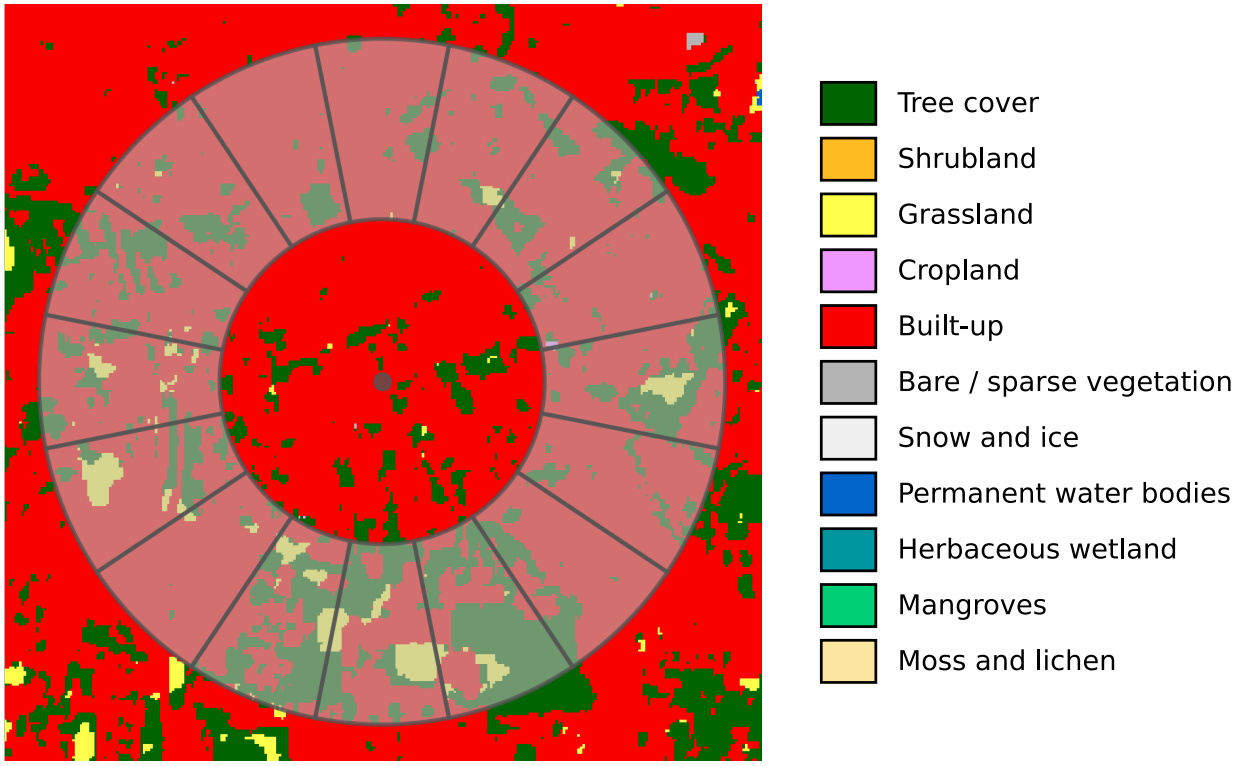


Figure 4: Illustration of land cover field and sectors used for setting surface roughness of the inlet velocity profile and terrain (ESA WorldCover 2021).

Surface roughness by wind direction

Wind direction	Surface roughness z0 (m)	Source
N	0.4 m	ESA WorldCover
NNE	0.4 m	ESA WorldCover
NE	0.4 m	ESA WorldCover
ENE	0.4 m	ESA WorldCover
E	0.4 m	ESA WorldCover
ESE	0.4 m	ESA WorldCover

Wind direction	Surface roughness z0 (m)	Source
SE	0.4 m	ESA WorldCover
SSE	0.4 m	ESA WorldCover
S	0.4 m	ESA WorldCover
SSW	0.4 m	ESA WorldCover
SW	0.4 m	ESA WorldCover
WSW	0.4 m	ESA WorldCover
W	0.4 m	ESA WorldCover
WNW	0.4 m	ESA WorldCover
NW	0.4 m	ESA WorldCover
NNW	0.4 m	ESA WorldCover

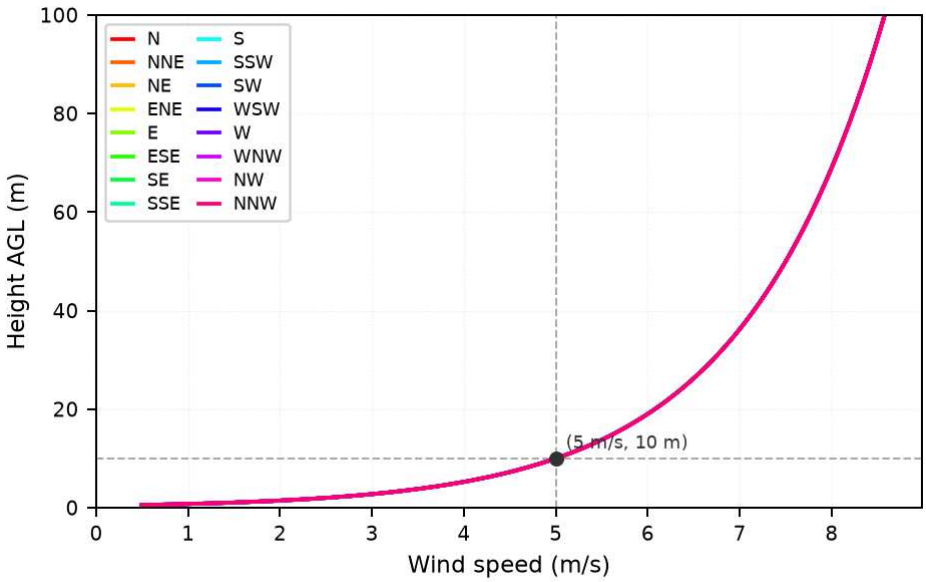


Figure 5: Log-law ABL inlet velocity profiles per wind direction. All profiles pass through the reference point (dashed lines); spread between curves reflects the per-direction surface roughness z_0.

Mapping of ESA WorldCover 2021 land cover classes to aerodynamic roughness lengths z_0. Values for permanent water bodies are computed dynamically using the Charnock relation.

Value	Land Cover Class	z_o (m)
0	No data	0.0002
10	Tree cover	0.4
20	Shrubland	0.07
30	Grassland	0.03
40	Cropland	0.1
50	Built-up	0.4
60	Bare / sparse vegetation	0.02
70	Snow and ice	0.001
80	Permanent water bodies	0.0002 (default) / Charnock relation
90	Herbaceous wetland	0.1
95	Mangroves	0.2
100	Moss and lichen	0.0024

For permanent water bodies, the static default roughness is 0.0002 m. However, when computing sector roughness, the Charnock relation is used instead to estimate a wind-speed-dependent roughness. The same Charnock-based estimate is applied to "No data" pixels within sectors.

Charnock relation for water surfaces

Over water, aerodynamic roughness depends on wave state, which itself depends on wind speed. ArchiWind estimates water surface roughness using a fitted Charnock-type relation:

$$z_0 = \frac{z}{\exp(B_n) - 1}$$

where B_n is a blended fit between low-wind (viscous) and high-wind (wave-dominated) regimes, and z is the reference height. The Charnock constant is $\alpha ch = 0.018$ and the kinematic viscosity of air is $\nu = 1.5 \times 10^{-5}$ m²/s. This computation is performed per wind direction using the sector mean wind speed, so water surface roughness varies by direction.

Assessment

NablaFlow has conducted a comprehensive wind analysis for the location. Using our proprietary ArchiWind platform, we performed detailed simulations incorporating historical wind data, surrounding building geometry, and terrain characteristics through **Computational Fluid Dynamics (CFD)**.

The analysis focuses on pedestrian-level wind comfort, which we evaluate based on the frequency of threshold wind speed exceedance. Following the **Lawson 2001 (Updated Lawson)** criteria, we classify comfort into the activity-based categories defined by the selected methodology so that every table, chart, and caption reflects the active standard.

Our findings identify critical wind-prone zones where sitting or standing may be challenging, along with the primary wind directions contributing to these conditions. We've mapped potential intervention areas both upstream and downstream where strategic mitigation measures could enhance comfort levels. Given the significant seasonal variations in both wind patterns and space utilization, we provide separate analyses for summer and winter conditions.

The success of this development depends on aligning wind comfort levels with intended space usage. For example, a terrace rated for walking in winter would require modifications to achieve sitting-level comfort for outdoor dining. Strategic placement of vegetation or wind screens can effectively shield such areas from prevailing winds.

For a complete understanding of our methodology and detailed findings, please refer to *https://docs.nablaflow.io/archiwind/guide/methodology/*

Summer analysis

In this part, we will focus on the wind simulation during the summer. In the northern hemisphere, outside of the tropics, this is the time when outdoor activities are favored by good weather conditions and thermal comfort. This section analyzes wind metrics for the period from May to October, which is how ArchiWind defines the summer half of the year. It includes an examination of wind statistics for this period, a wind comfort analysis at pedestrian level, and a detailed assessment of problematic areas with mitigation strategies. This section also highlights the wind directions that pose the greatest risk to pedestrian comfort in the control area.

Wind statistics analysis

In this section, we will higlight the critical wind directions.

A wind rose is a graphical representation used by meteorologists to illustrate the distribution of wind speed and direction at a specific location. It provides a concise view of wind patterns, with spokes indicating the frequency of wind from each direction. Color bands represent different wind speed ranges, allowing for quick identification of prevailing wind directions.

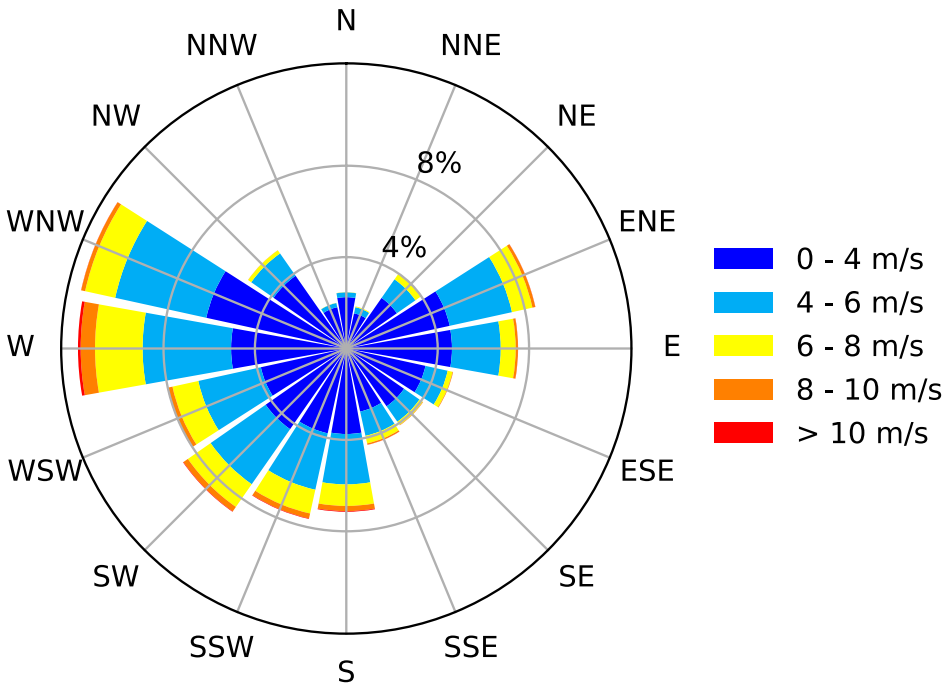


Figure 6: Summer: April - September

The wind rose for the summer period highlights the dominant wind directions: west-northwest, west and southwest.
These directions are most frequent during this period but are not necessarily the most problematic.
Problematic wind directions are characterized by high frequency combined with strong wind speeds, typically represented by orange and red bands.

The next figure provides a detailed distribution of wind speeds for each direction, offering

deeper insights into the severity of wind conditions across all directions.

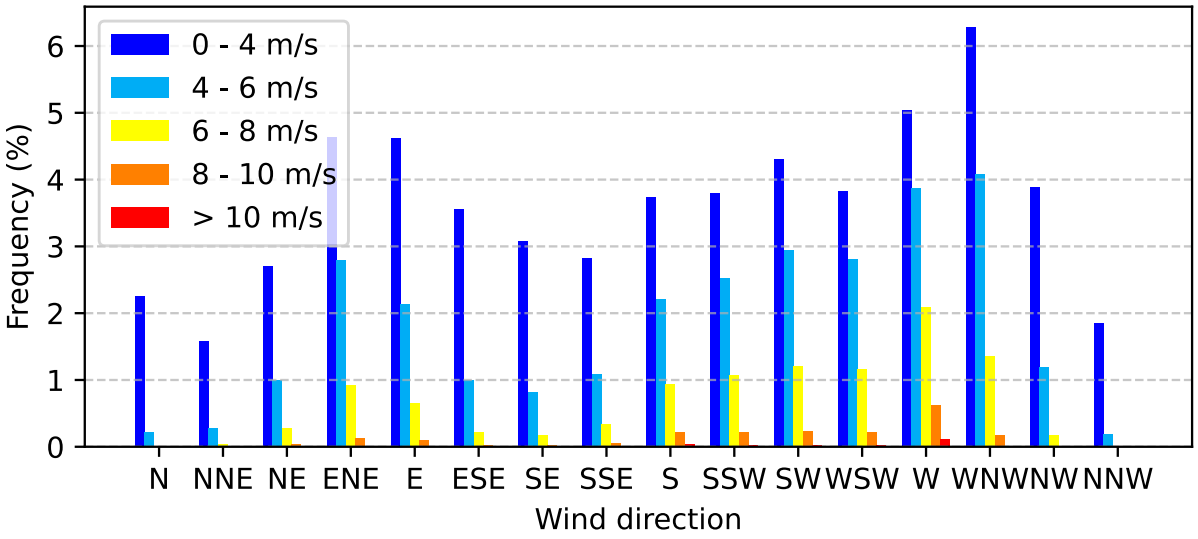


Figure 7: Summer - Wind speed distribution

Pedestrian wind comfort analysis in focus area

This section presents a comprehensive evaluation of pedestrian wind comfort and its spatial distribution across the control area. Using the established Lawson 2001 (Updated Lawson) comfort criteria, we conduct quantitative comparisons between design scenarios, with a primary focus on maximizing areas suitable for extended outdoor use (indicated by dark and light blue regions). Based on the distribution of comfort zones and the presence of any high-discomfort areas, we assign an overall Comfort Label to assess the site's performance.



Figure 8: Summer - Full domain

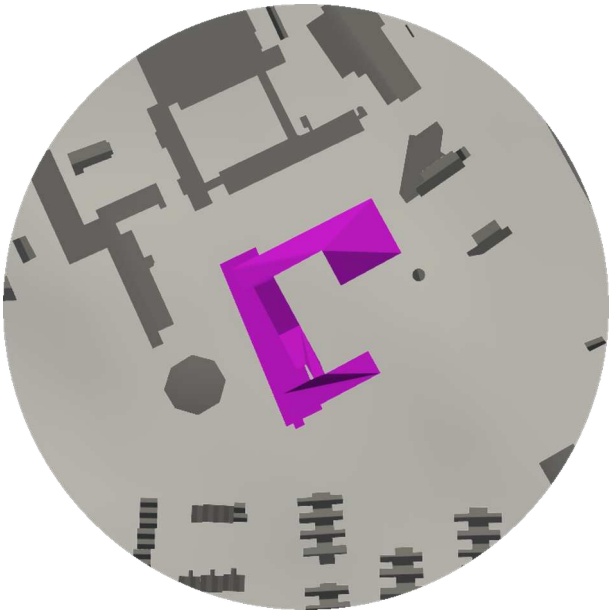


Figure 9: Summer - Zone of interest

Our assessment has identified **2509.27 m²** of areas of **moderate-risk zones near the building.**
While not severe, these areas would benefit from targeted mitigation measures to enhance pedestrian safety and comfort.

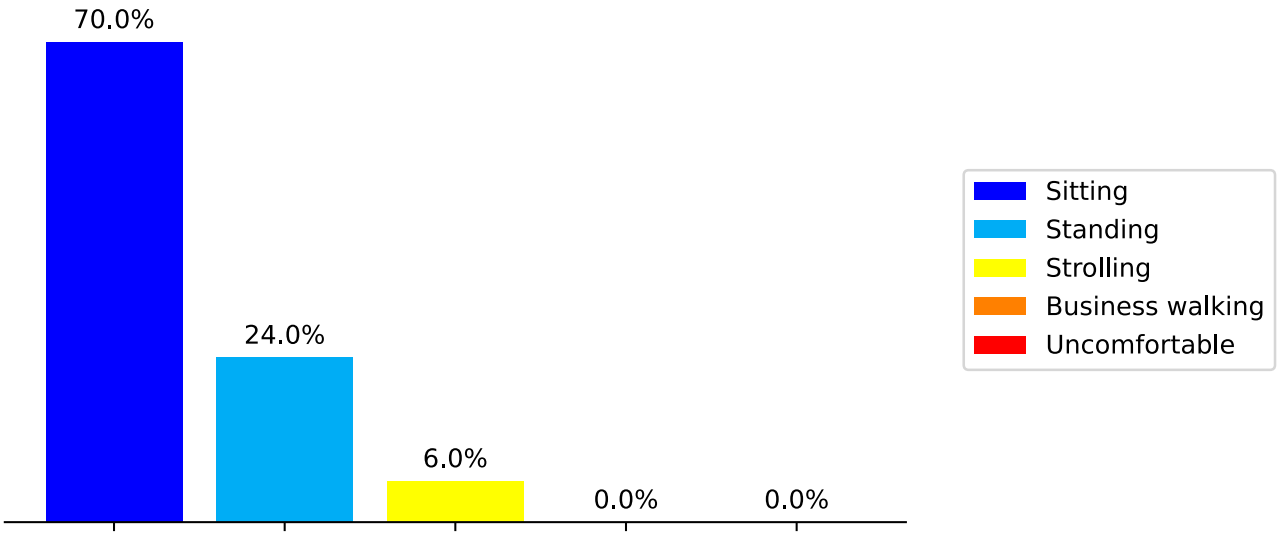


Figure 10: Summer - Pedestrian comfort in the control area (terrain)

Based on our comprehensive evaluation, the site's pedestrian wind comfort during the summer period is classified as **very comfortable**. This rating reflects the overall suitability of the space for various outdoor activities during this seasonal period.

During the summer period, wind comfort class **very comfortable** predominates, encompassing **62325.59 m²** (**~69.8%** of the control area).

High-comfort zones (the most permissive classes in **Lawson 2001 (Updated Lawson)**) cover **83741.36 m²** (**~93.7%** of the control area). These spaces are optimal for outdoor dining, recreational seating, and leisurely pedestrian activities.

Areas requiring attention (the most restrictive classes in **Lawson 2001 (Updated Lawson)**) span **0.61 m²** (**~0.0%** of the control area). These locations experience wind conditions that warrant consideration for comfort-improvement measures to enhance the overall site usability.

Directional analysis for problematic areas

This section presents a detailed analysis of areas exhibiting reduced pedestrian wind comfort (*pedestrian wind comfort levels 4 and 5*) across seasonal variations. Our assessment identifies critical wind directions contributing to these suboptimal conditions and pinpoints strategic locations where mitigation measures would be most effective. To provide a comprehensive understanding, we analyze both the frequency of occurrence and velocity distributions of these problematic wind directions, enabling data-driven decisions for implementing comfort improvement measures.

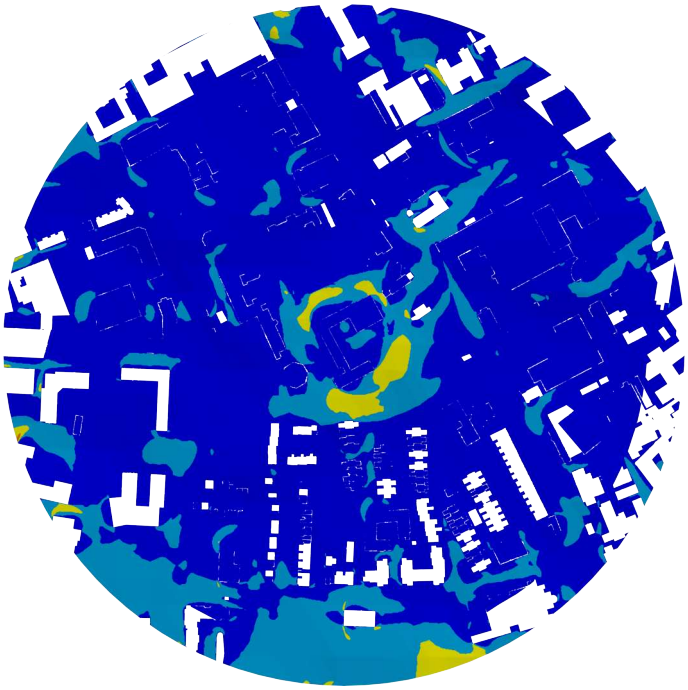


Figure 11: Summer - Problematic areas in pedestrian wind comfort

The wind comfort analysis conducted for the summer period demonstrates **favorable conditions across the entire site of interest**. Based on established comfort criteria, the area is **highly suitable** for all types of pedestrian activities, including stationary uses such as outdoor dining, recreational seating, and children's play areas. Our assessment indicates that comfortable conditions are expected to prevail approximately 95% of the time, **well within acceptable standards for urban spaces**.

Winter analysis

In this part, we will focus on the wind simulation during the winter. In the northern hemisphere, outside of the tropics, this period is marked by colder temperatures and less frequent outdoor activity due to harsher weather conditions. This section analyzes wind metrics for the period from November to April, the complementary winter block in our seasonal split. It includes an examination of wind statistics for this period, a wind comfort analysis at pedestrian level, and an evaluation of areas where wind effects may exacerbate thermal discomfort. This section also highlights the wind directions that contribute most significantly to pedestrian discomfort in the control area.

Wind statistics analysis

In this section, we will higlight the critical wind directions.

A wind rose is a graphical representation used by meteorologists to illustrate the distribution of wind speed and direction at a specific location. It provides a concise view of wind patterns, with spokes indicating the frequency of wind from each direction. Color bands represent different wind speed ranges, allowing for quick identification of prevailing wind directions.

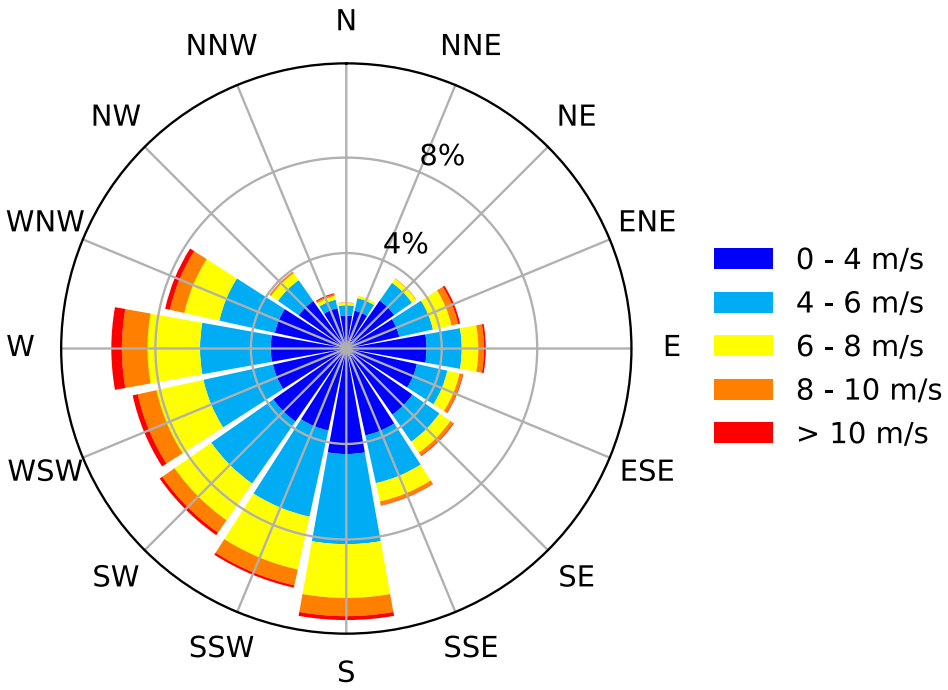


Figure 12: Winter: October - March

The wind rose for the winter period highlights the dominant wind directions: south, south-southwest and west.
These directions are most frequent during this period but are not necessarily the most problematic.
Problematic wind directions are characterized by high frequency combined with strong wind speeds, typically represented by orange and red bands.

The next figure provides a detailed distribution of wind speeds for each direction, offering

deeper insights into the severity of wind conditions across all directions.

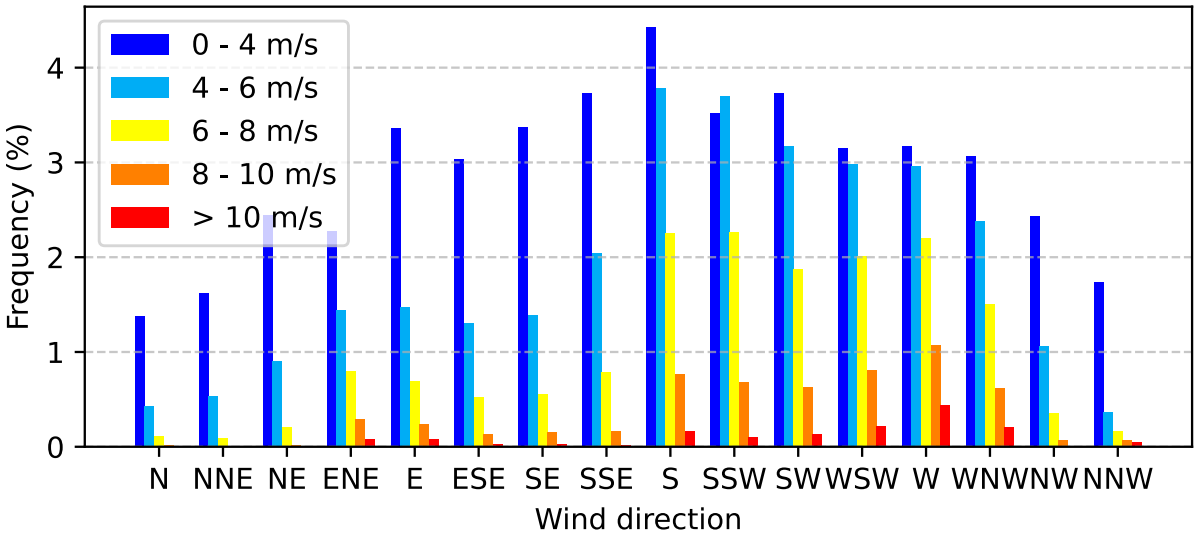


Figure 13: Winter - Wind speed distribution

Pedestrian wind comfort analysis in focus area

This section presents a comprehensive evaluation of pedestrian wind comfort and its spatial distribution across the control area. Using the established Lawson 2001 (Updated Lawson) comfort criteria, we conduct quantitative comparisons between design scenarios, with a primary focus on maximizing areas suitable for extended outdoor use (indicated by dark and light blue regions). Based on the distribution of comfort zones and the presence of any high-discomfort areas, we assign an overall Comfort Label to assess the site's performance.



Figure 14: Winter - Full domain

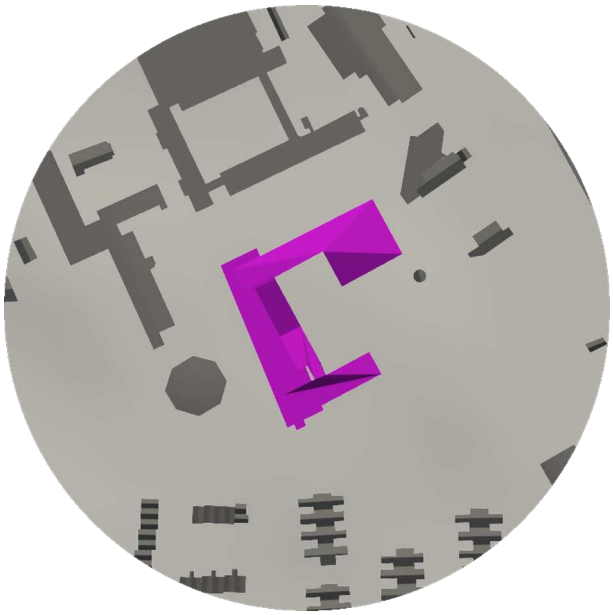


Figure 15: Winter - Zone of interest

Our assessment has identified **6782.04 m²** of areas of **moderate-risk zones near the building.**
While not severe, these areas would benefit from targeted mitigation measures to enhance pedestrian safety and comfort.

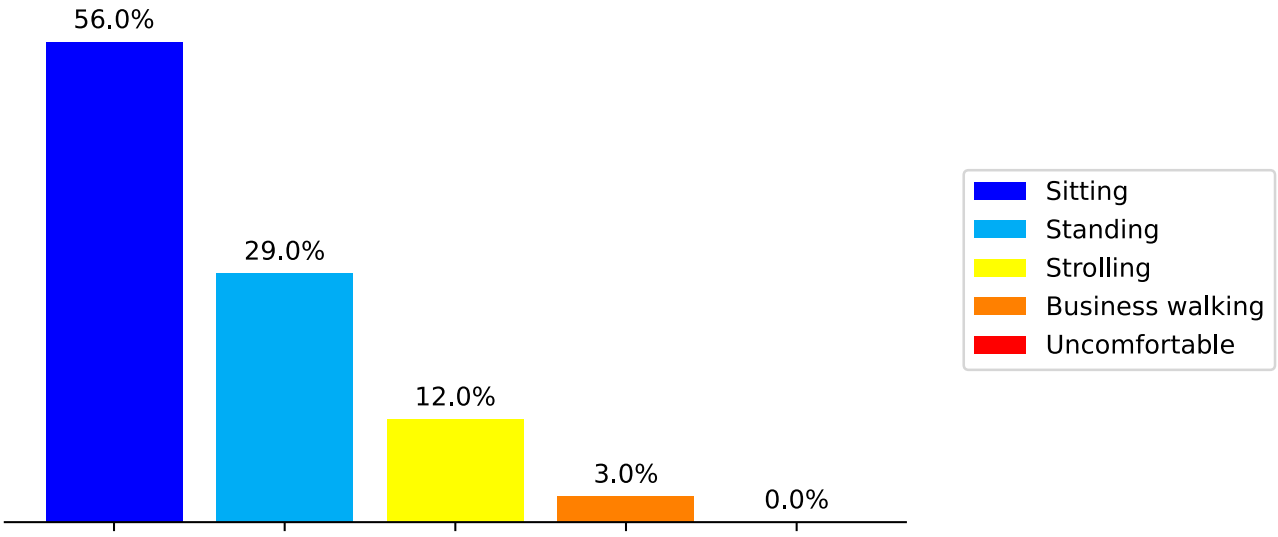


Figure 16: Winter - Pedestrian comfort in the control area (terrain)

Based on our comprehensive evaluation, the site's pedestrian wind comfort during the winter period is classified as **very comfortable**. This rating reflects the overall suitability of the space for various outdoor activities during this seasonal period.

During the winter period, wind comfort class **very comfortable** predominates, encompassing **49993.62 m²** (**~56.0%** of the control area).

High-comfort zones (the most permissive classes in **Lawson 2001 (Updated Lawson)**) cover **75477.68 m²** (**~84.5%** of the control area). These spaces are optimal for outdoor dining, recreational seating, and leisurely pedestrian activities.

Areas requiring attention (the most restrictive classes in **Lawson 2001 (Updated Lawson)**) span **2749.51 m²** (**~3.1%** of the control area). These locations experience wind conditions that warrant consideration for comfort-improvement measures to enhance the overall site usability.

Directional analysis for problematic areas

This section presents a detailed analysis of areas exhibiting reduced pedestrian wind comfort (*pedestrian wind comfort levels 4 and 5*) across seasonal variations. Our assessment identifies critical wind directions contributing to these suboptimal conditions and pinpoints strategic locations where mitigation measures would be most effective. To provide a comprehensive understanding, we analyze both the frequency of occurrence and velocity distributions of these problematic wind directions, enabling data-driven decisions for implementing comfort improvement measures.

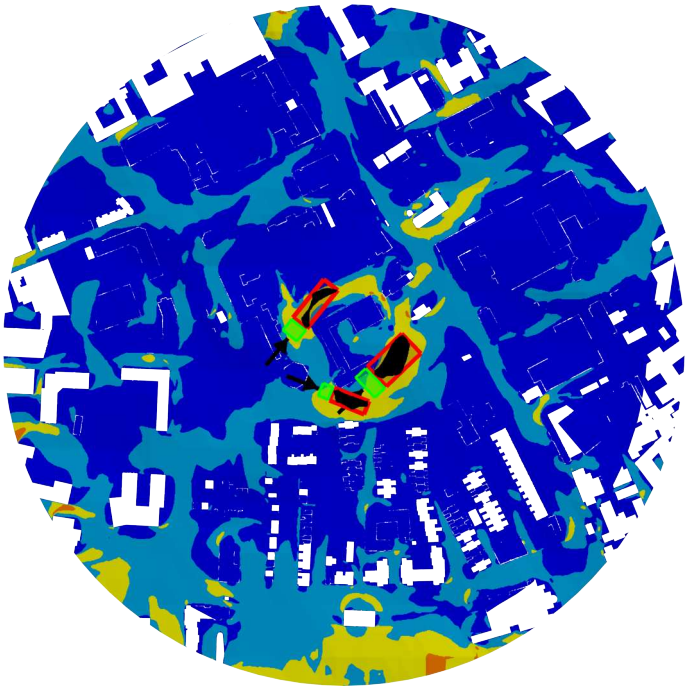
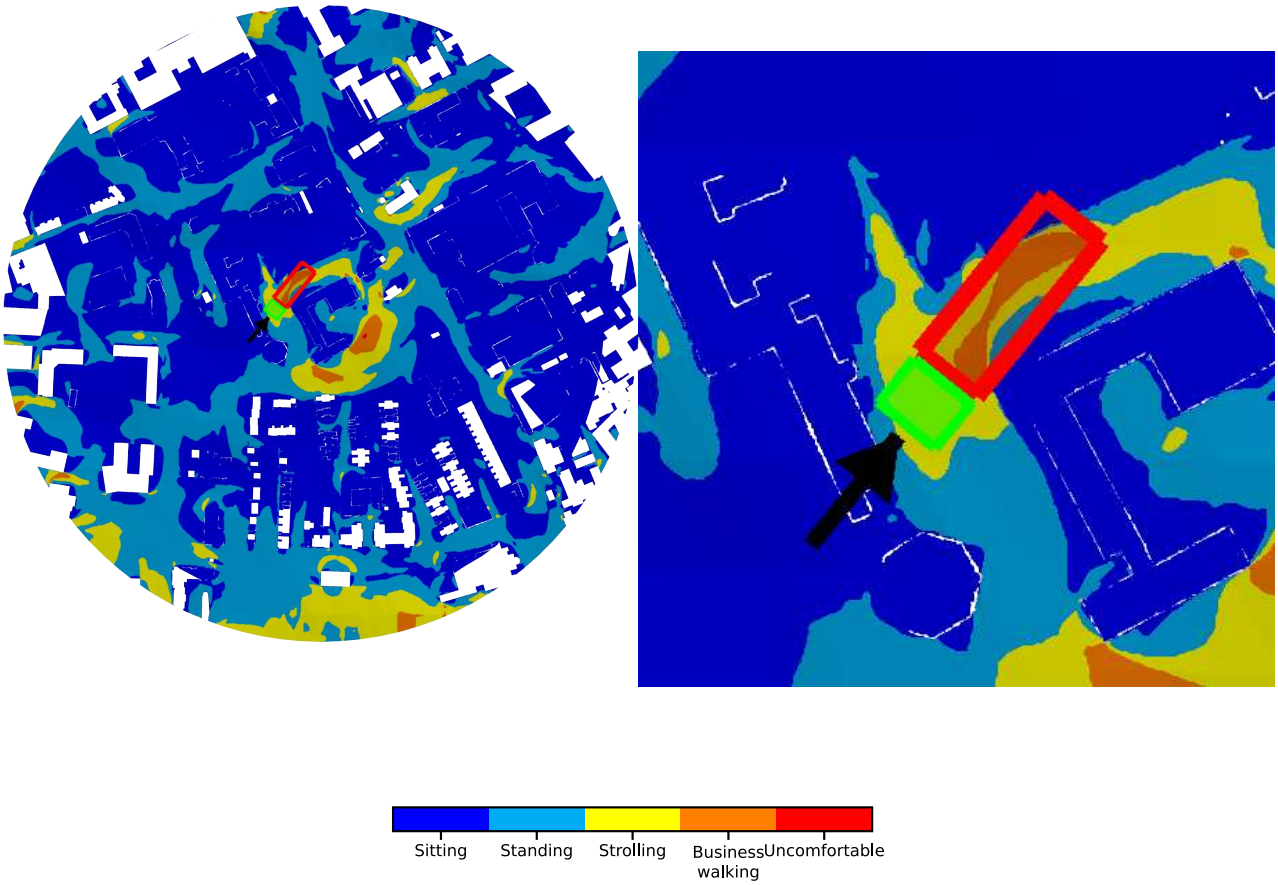


Figure 17: Winter - Problematic areas in pedestrian wind comfort



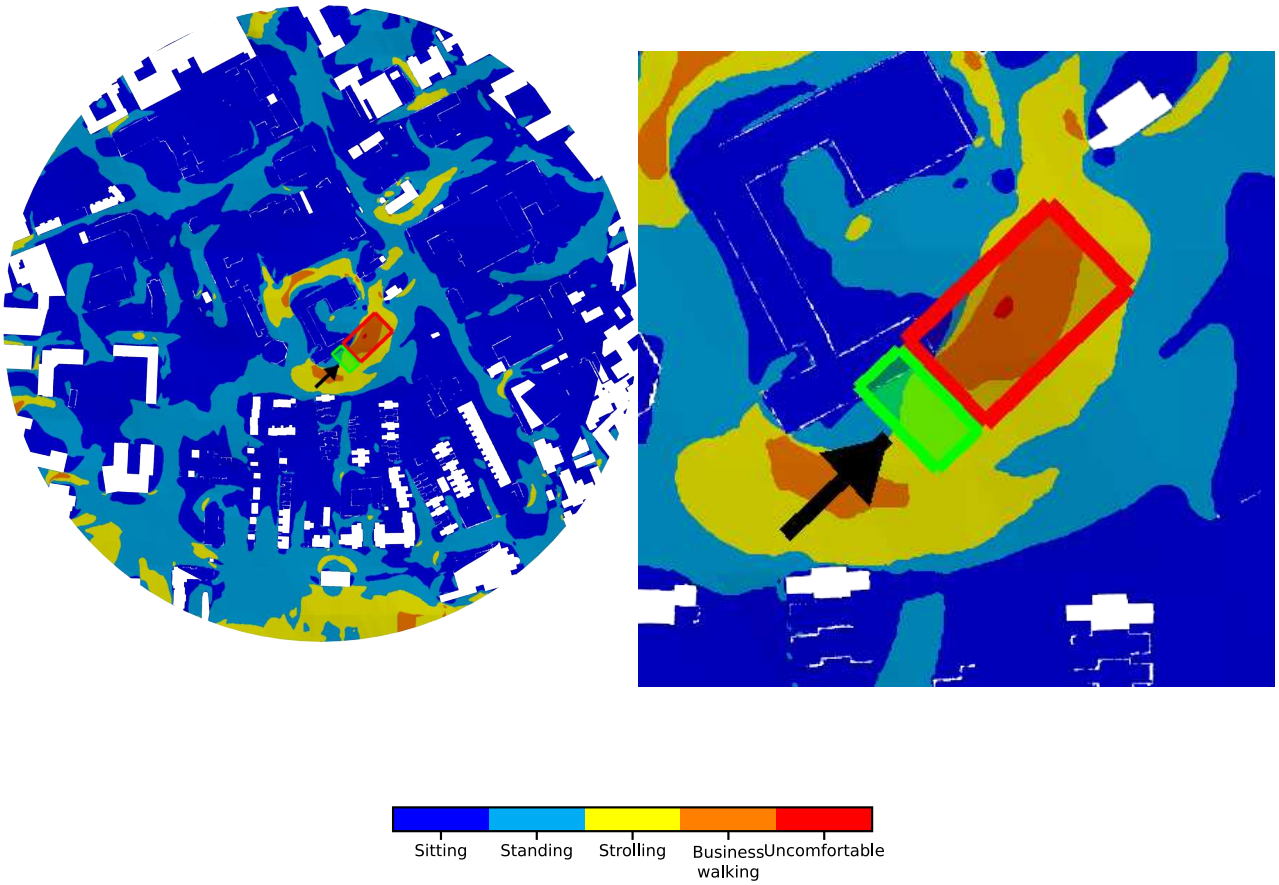
Our comprehensive wind assessment has identified **3 areas of concern** within the site during the winter period that require attention.
These locations experience wind conditions that **may impact pedestrian comfort and safety**. The following analysis presents a detailed examination of each area, combining both qualitative assessments through wind speed simulation visualization and quantitative statistical analysis of wind frequency and velocity distributions.

Zone #1 requires specific attention due to wind-induced comfort concerns. Critical wind effects originate predominantly from direction **south-southwest**, creating conditions that fall below desired comfort thresholds. Our analysis indicates that implementing wind mitigation measures within the designated green zone would provide optimal effectiveness in improving local comfort conditions.,



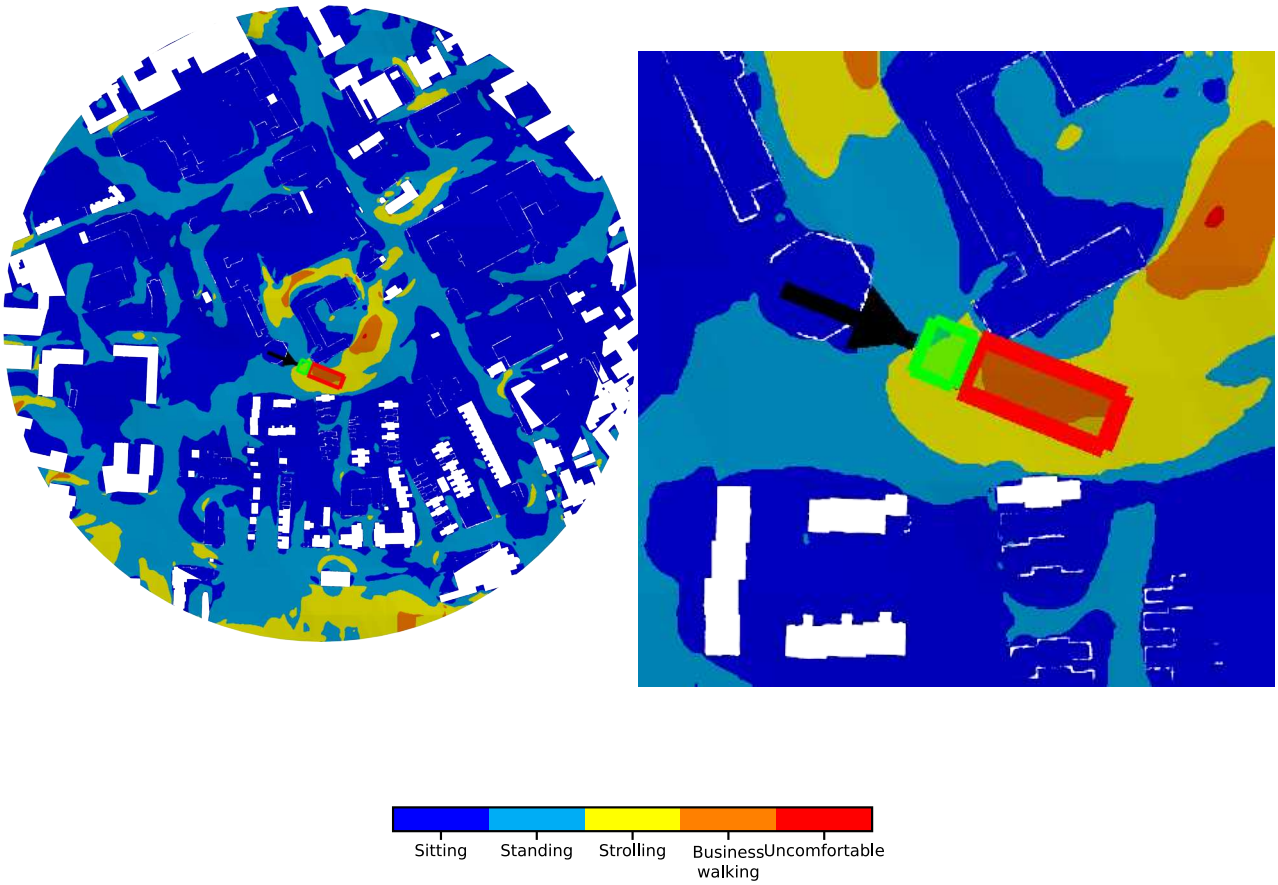
To make well-informed decisions, a detailed analysis of the wind from **south-southwest** is essential. This particular wind direction occurs 10 percent of the time. The frequency of occurrence is a critical factor in determining mitigation priorities - higher frequency wind directions require more urgent attention, while lower frequency cases may be considered less critical in our mitigation strategy.

Zone #2 requires specific attention due to wind-induced comfort concerns. Critical wind effects originate predominantly from direction **south-southwest**, creating conditions that fall below desired comfort thresholds. Our analysis indicates that implementing wind mitigation measures within the designated green zone would provide optimal effectiveness in improving local comfort conditions.,



To make well-informed decisions, a detailed analysis of the wind from **south-southwest** is essential. This particular wind direction occurs 10 percent of the time. The frequency of occurrence is a critical factor in determining mitigation priorities - higher frequency wind directions require more urgent attention, while lower frequency cases may be considered less critical in our mitigation strategy.

Zone #3 requires specific attention due to wind-induced comfort concerns. Critical wind effects originate predominantly from direction **west**, creating conditions that fall below desired comfort thresholds. Our analysis indicates that implementing wind mitigation measures within the designated green zone would provide optimal effectiveness in improving local comfort conditions.,



To make well-informed decisions, a detailed analysis of the wind from **west** is essential. This particular wind direction occurs 10 percent of the time. The frequency of occurrence is a critical factor in determining mitigation priorities - higher frequency wind directions require more urgent attention, while lower frequency cases may be considered less critical in our mitigation strategy.

Results

Pedestrian wind comfort

Terrain

Wind comfort maps for the location are shown in figures 18, 19 and 20. The map show which activities are suitable for each area based on the wind comfort criteria and local wind speed 1.5 meters above pedestrian-level obtained from wind simulations. Since both the wind conditions and the use of the area can differ between the seasons, comfort maps for summer and winter are shown separately. Since the comfort classification is discrete, small local changes from one comfort class to another can be due to relatively small changes in wind conditions.

Since the wind comfort maps are based on a weighted average of several simulations with different wind directions, we must look more closely at the respective simulations to understand the causes of any changes. Figures showing the wind speed at pedestrian-level with wind from 16 different directions can be found as attachments to the report. By studying these in conjunction with the local wind rose in figure 3, one can better understand what causes the changes in wind comfort.

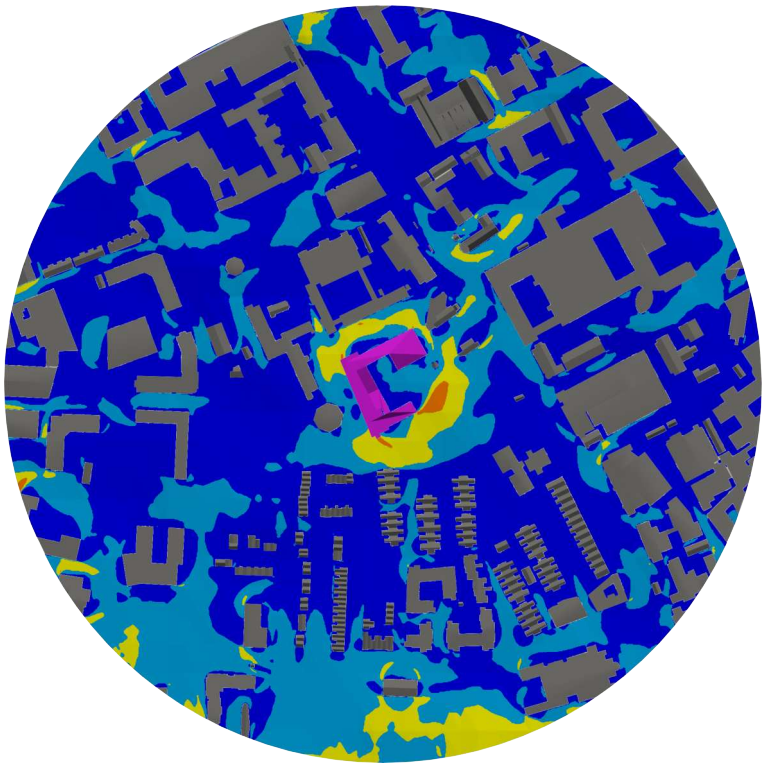


Figure 18: Wind comfort map (Lawson 2001 (Updated Lawson)) for the full year, 1.5 meters above pedestrian-level.

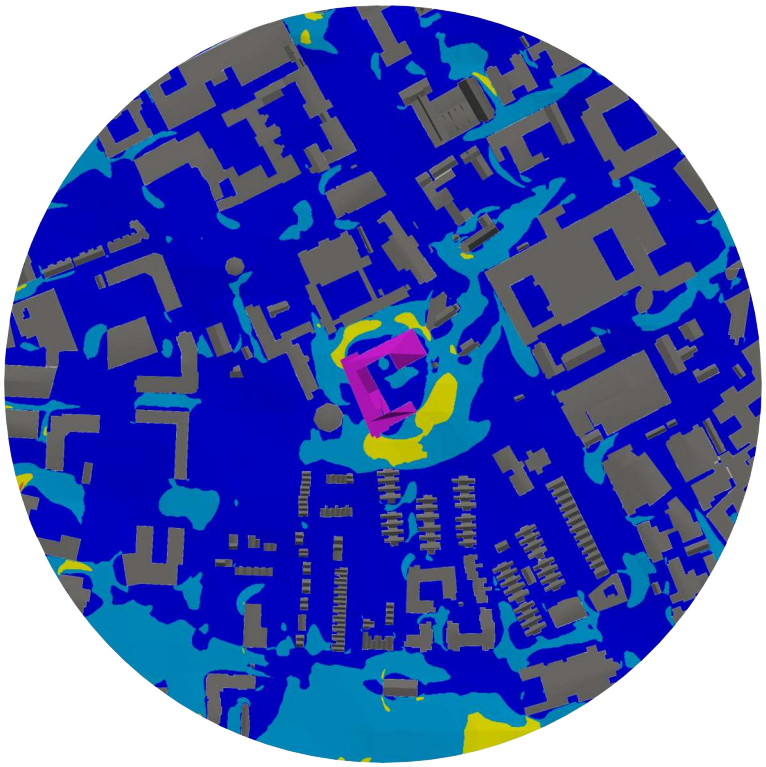


Figure 19: Wind comfort map (Lawson 2001 (Updated Lawson)) for the summer season, 1.5 meters above pedestrian-level.

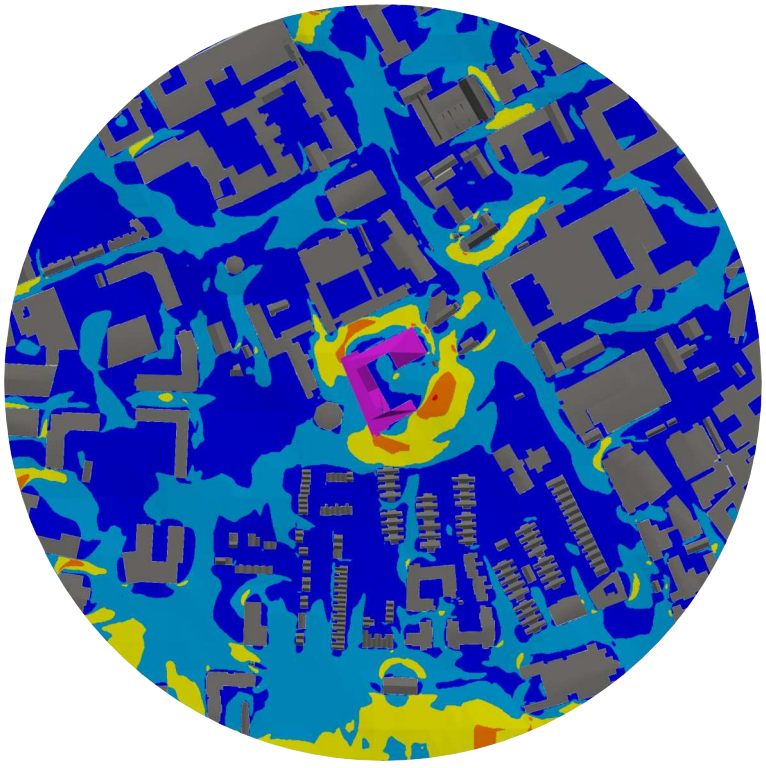


Figure 20: Wind comfort map (Lawson 2001 (Updated Lawson)) for the winter season, 1.5 meters above pedestrian-level.



Pedestrian wind comfort

Buildings

The wind comfort on the roofs and balconies/terraces of new buildings is shown in figures 21, 22 and 23 for the different seasons. This is given 1.5 meters above the local height of the building. "Built area" includes everything that is not part of the terrain, i.e., roofs and balconies/terraces on new buildings and new park areas that are part of the 3D models.

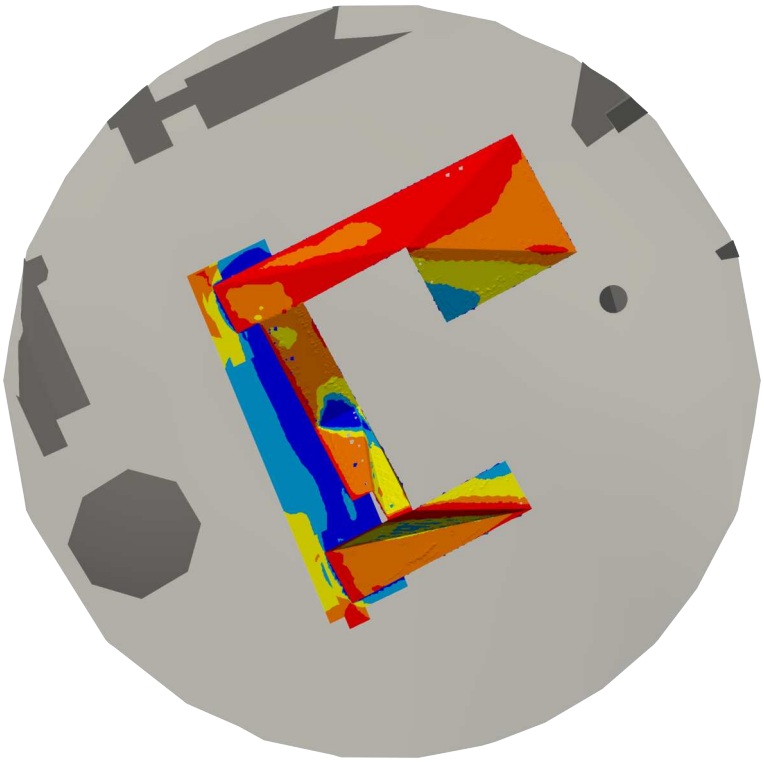


Figure 21: Wind comfort (Lawson 2001 (Updated Lawson)) for the full year over buildings, 1.5 meters above local building height.



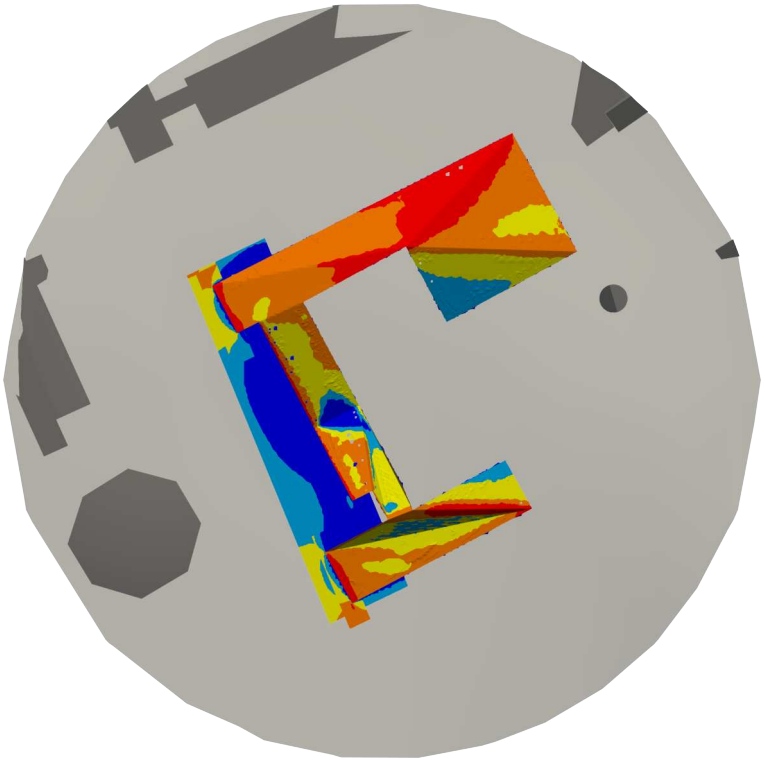


Figure 22: Wind comfort (Lawson 2001 (Updated Lawson)) for the summer season over buildings, 1.5 meters above local building height.

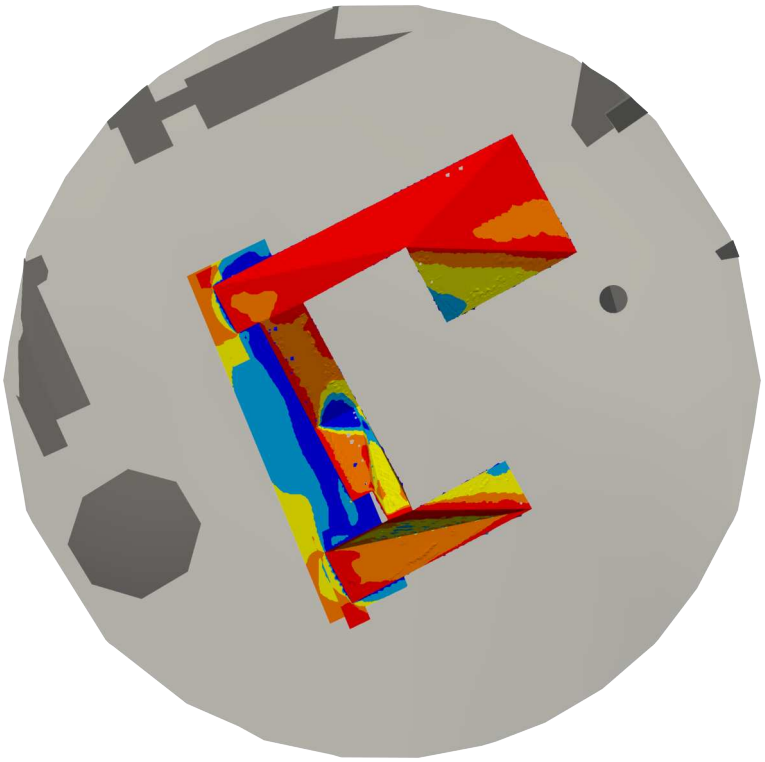


Figure 23: Wind comfort (Lawson 2001 (Updated Lawson)) for the winter season over buildings, 1.5 meters above local building height.



Wind safety on terrain

Wind safety maps are shown in 24, 25 and 26 for the different seasons. Wind safety categorizes areas where high wind speeds, imposing a risk on personal safety, could potentially occur.



Figure 24: Wind safety map (NEN 8100 (mean wind at 2 m)) for the full year, 1.5 meters above pedestrian-level.



Figure 25: Wind safety map (NEN 8100 (mean wind at 2 m)) for the summer season, 1.5 meters above pedestrian-level.



Figure 26: Wind safety map (NEN 8100 (mean wind at 2 m)) for the winter season, 1.5 meters above pedestrian-level.



Average wind speed on terrain

Average wind speed 1.5 meters above pedestrian-level for the proposed buildings is shown in figure 27, 28 and 29 for the different seasons. Average wind speed represents a weighted average of the local wind speed based on wind simulations and wind statistics for the area.

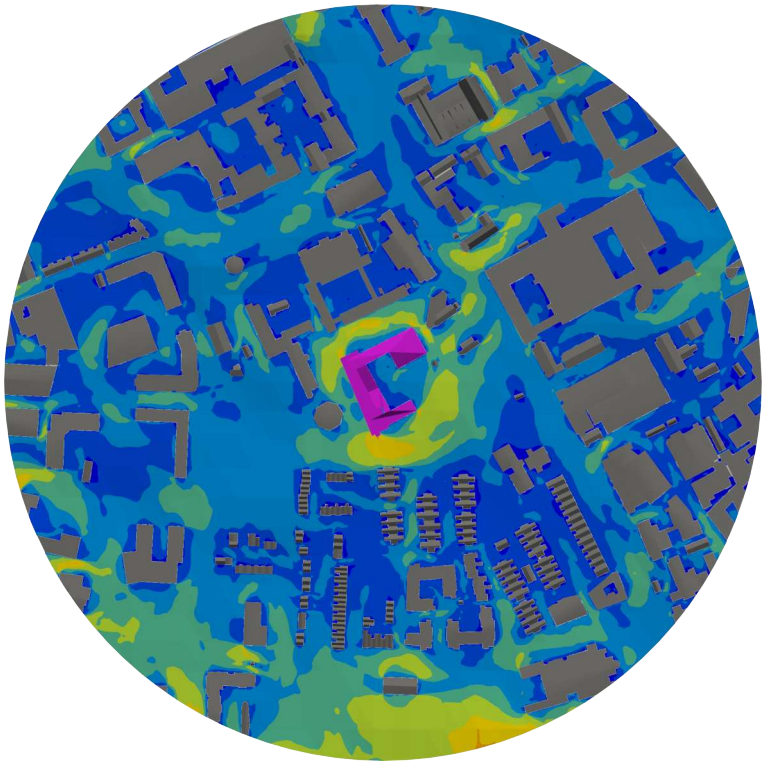
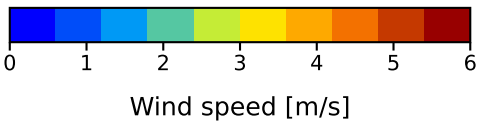


Figure 27: Average wind speed for the full year, 1.5 meters above pedestrian-level.



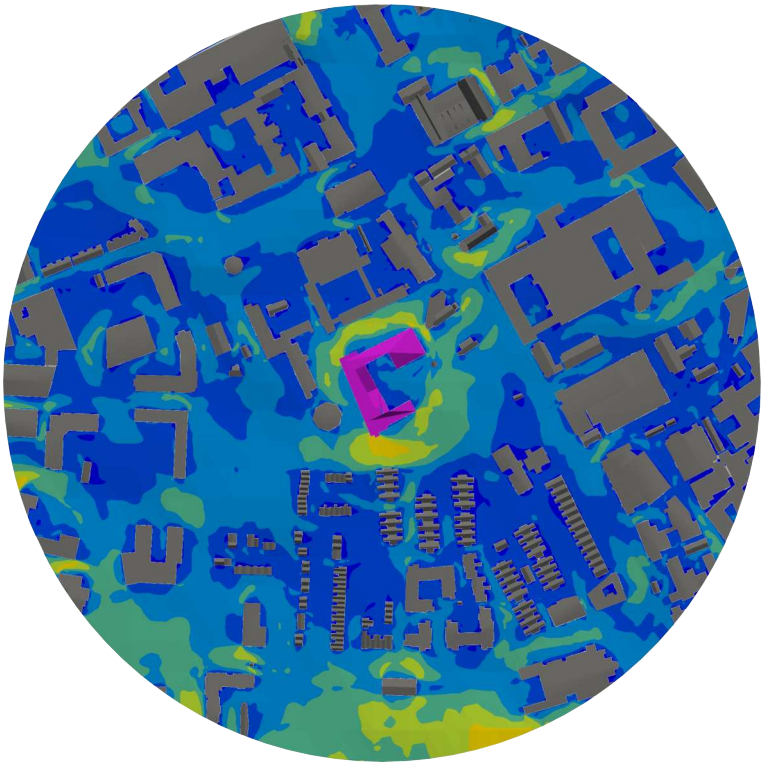


Figure 28: Average wind speed for the summer season, 1.5 meters above pedestrian-level.

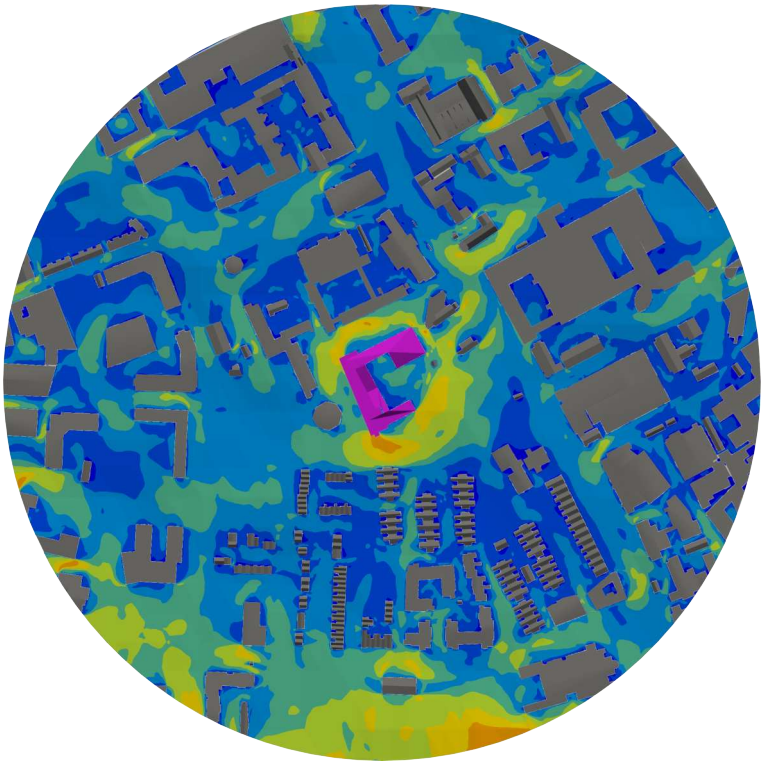
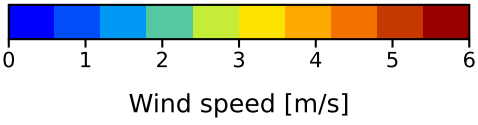


Figure 29: Average wind speed for the winter season, 1.5 meters above pedestrian-level.



Average wind power density on buildings

Average wind power density 1.5 meters above local building height for the proposed buildings is shown in figure 30, 31 and 32 for the different seasons. Power density shows the total power of the mean wind per area in units of Watts per square meter, and is based on local wind simulations and wind statistics for the area.

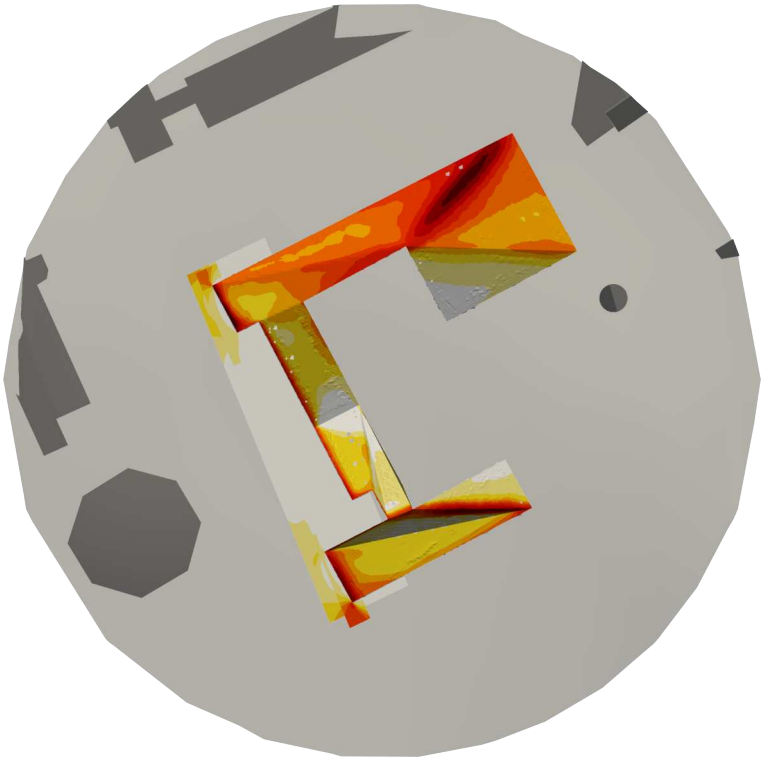
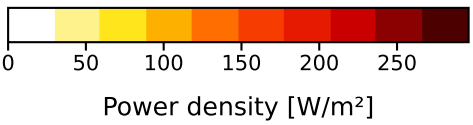


Figure 30: Average wind power density for the full year, 1.5 meters above pedestrian-level.



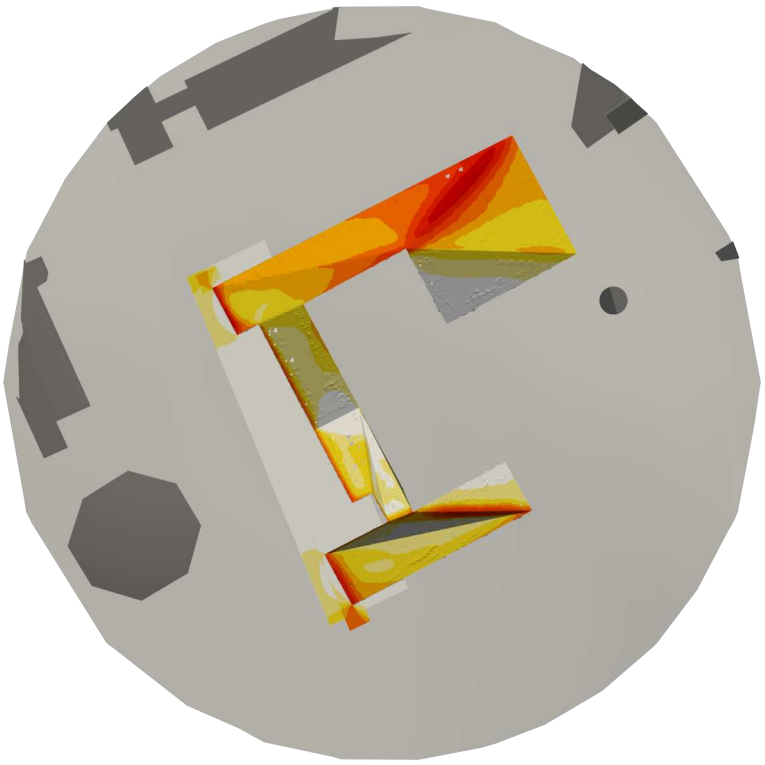


Figure 31: Average wind power density for the summer season, 1.5 meters above pedestrian-level.

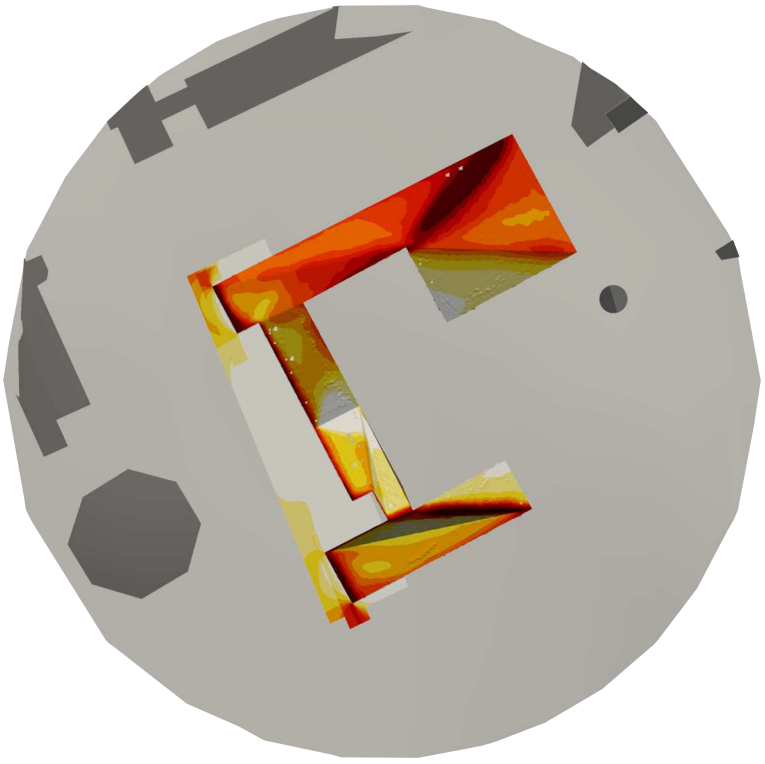
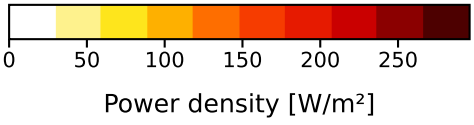
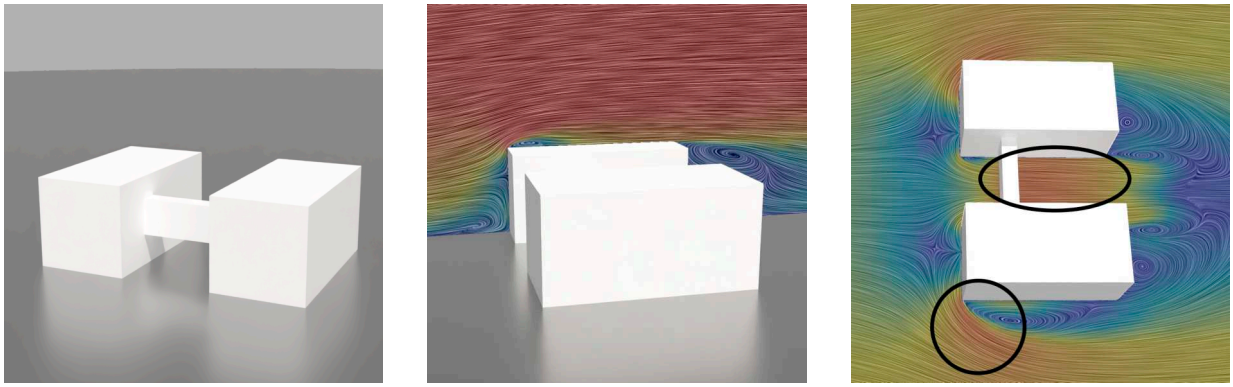


Figure 32: Average wind power density for the winter season, 1.5 meters above pedestrian-level.

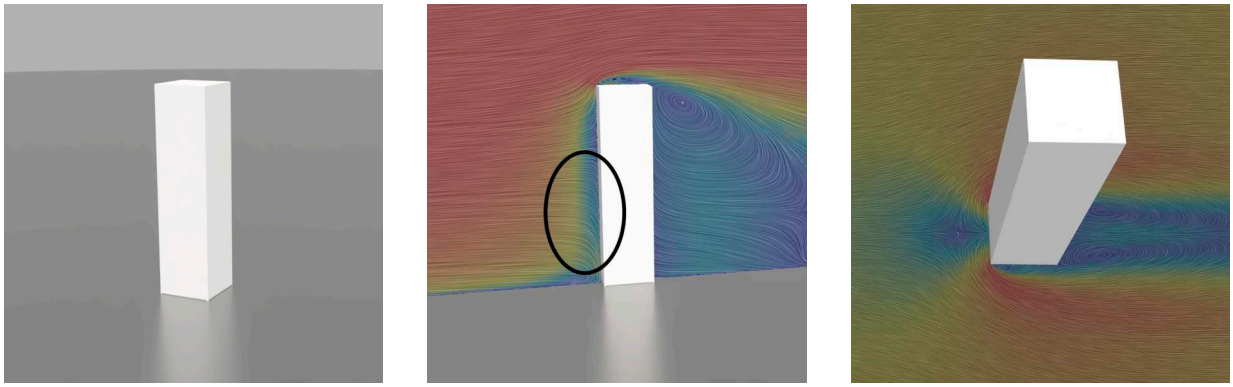


Effect of buildings on wind conditions

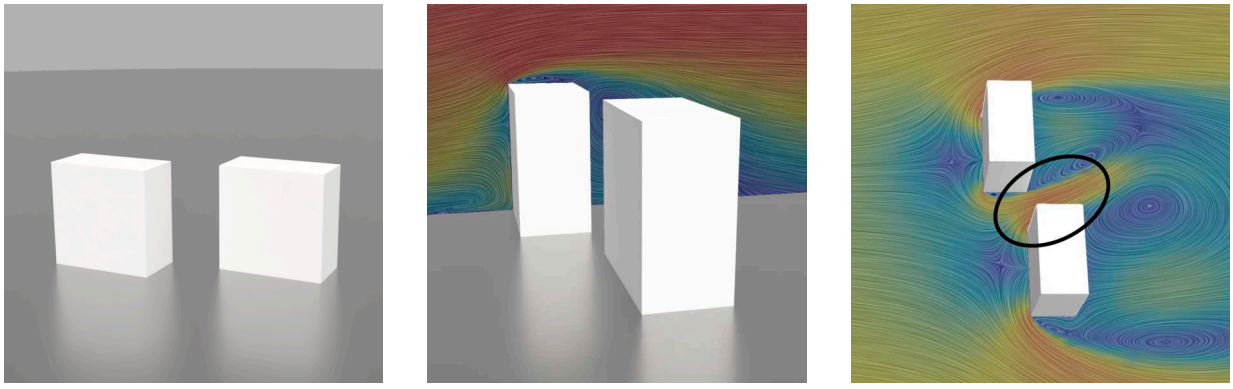
It can be difficult to predict wind conditions for complex building geometries and topography intuitively. Therefore, it is appropriate to use numerical simulation models that use physical laws to simulate the wind field in detail. However, some typical phenomena to be aware of can lead to problems with wind comfort, illustrated in Figure 33.



Acceleration around sharp corners and under skybridge.



Downwash in front of tall building.



Passageway jet between buildings.

Figure 33: Illustration of general, local effects of wind around buildings.

When the wind hits a building, an overpressure on the facade facing the wind direction will occur, and the wind will be pushed around the building. This causes the wind to accelerate around corners and through openings. Especially for tall buildings, high acceleration of the wind down to the pedestrian-level on the lee side can also occur. If two buildings stand close to each other or several buildings are closely grouped, the wind

can accelerate in passages between the buildings. It is important to note that these phenomena will only sometimes lead to problems. The local wind conditions result from a complex interaction between the size and shape of the buildings, surrounding development, topography, and overall wind conditions. An analysis using numerical flow simulations will provide a more detailed and nuanced picture of the actual wind comfort in the areas around the building.

General wind comfort mitigation strategies

This section outlines key architectural and landscaping strategies that can effectively improve pedestrian wind comfort. Each measure can be implemented individually or in combination, depending on site-specific requirements and conditions.

Vegetation Strategies
Strategic placement of vegetation serves as an effective natural wind barrier.
Different types of vegetation offer varying benefits:
- **Dense Trees**: Create substantial wind reduction zones extending 3-5 times the tree height downwind.
- **Evergreen Hedges**: Provide year-round protection and can reduce wind speeds by 20-40%.
- **Tiered Planting**: Combining trees with lower vegetation maximizes wind speed reduction at multiple heights.
- **Seasonal Considerations**: Consider using deciduous trees where summer shade is desired but winter sun penetration is important.

Wind Screen Implementation
Artificial wind screens can be both functional and aesthetically pleasing:
- **Porous Screens**: 20-30% porosity typically provides optimal wind reduction while preventing turbulence.
- **Height Considerations**: Effective screens should be at least 2-2.5m tall for pedestrian areas.
- **Positioning**: Most effective when placed perpendicular to problematic wind directions.
- **Integration**: Can be combined with seating areas or artistic elements to enhance urban design.

Building Height Considerations
The relationship between building height and wind effects requires careful consideration:
- **Downwash Effect**: Tall buildings can direct high-altitude winds to pedestrian-level, increasing local wind speeds areas.
- **Podium Design**: Including a podium of 3-5 stories can effectively redirect downwash away from pedestrian.
- **Stepped Facades**: Gradually stepping back upper floors can help dissipate downward wind flows.
- **Height Transitions**: Gradual transitions between buildings of different heights reduce adverse wind effects.

Corner Treatment Strategies

Building corners require special attention due to their potential to accelerate wind speeds:
- **Rounded Corners**: Can reduce corner wind speeds by up to 25% compared to sharp corners.
- **Chamfered Edges**: 45° angles help deflect wind flows more gradually.
- **Canopies**: Horizontal projections at corner locations can redirect downward wind flows.
- **Architectural Features**: Vertical fins or textured surfaces can help break up wind flows around corners.

Passage Design Guidelines
Careful design of passages between buildings is crucial for pedestrian comfort:
- **Width-to-Height Ratio**: Maintain a minimum ratio of 1:3 to prevent excessive wind acceleration.
- **Entrance Design**: Graduated openings or screening at passage entrances can reduce wind tunnel effects.
- **Alternative Routes**: Provide sheltered alternative paths during high-wind conditions.
- **Surface Roughness**: Increasing ground surface roughness through landscaping or textured paving can reduce wind speeds.

Implementation Considerations
When implementing these measures, consider the following factors:
- **Local Climate**: Adapt solutions to seasonal wind patterns and weather conditions.
- **Urban Context**: Ensure compatibility with surrounding architecture and urban design guidelines.
- **Maintenance Requirements**: Consider long-term maintenance needs and costs.
- **Multiple Benefits**: Prioritize solutions that address wind comfort while providing additional benefits such as shade, aesthetics, or social spaces.

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ARCHIWIND

Contacts

NablaFlow AS

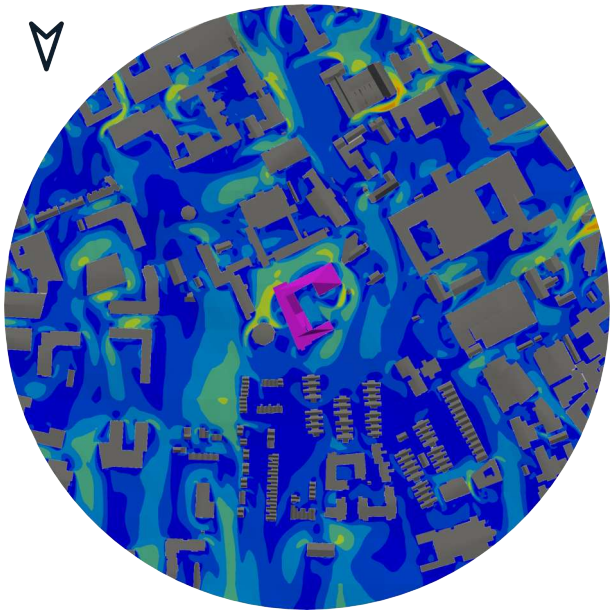
Address	Sverdrups gate 27 4007 Stavanger
Email	info@nablaflow.io
Website	https://nablaflow.io

Appendix

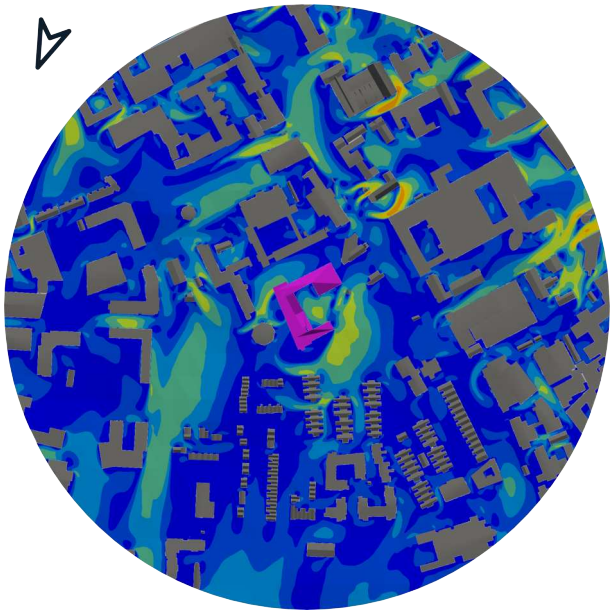
A - Wind speed on terrain

A detailed visualization showing the local wind speed is presented here. These can be used to evaluate the causes of local wind comfort and identify problematic wind directions.

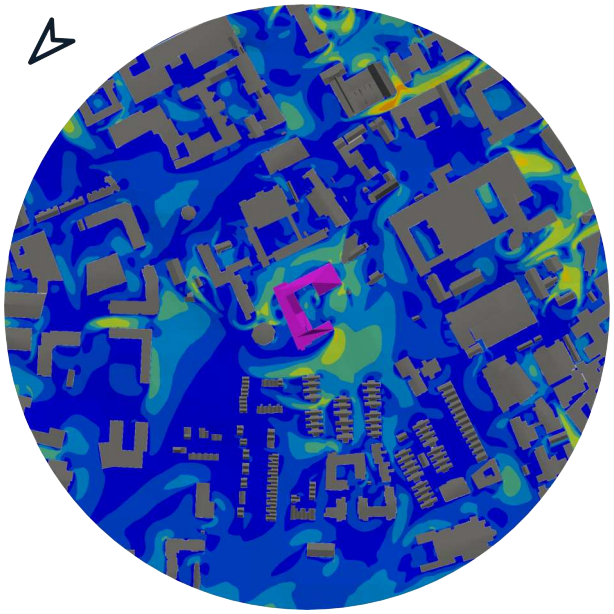
Figure 34, 35, 36 and 37 shows the wind speed scaling factor 1.5 meters above pedestrian-level for 16 wind directions. The scaling factor shows the relation between the local wind speed and the regional reference wind speed. In meteorology, wind speed is typically reported at a height of 10 meters above pedestrian-level. Therefore, the reference wind speed (Uref) used in the simulations is also defined as 10 meters above pedestrian-level.



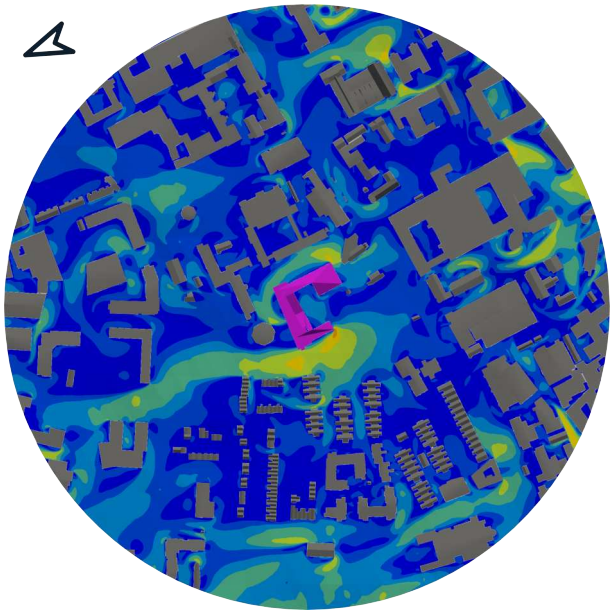
Wind dir: 0.0°. Yearly frequency for sector: 2%.



Wind dir: 22.5°. Yearly frequency for sector: 2%.



Wind dir: 45.0°. Yearly frequency for sector: 4%.



Wind dir: 67.5°. Yearly frequency for sector: 7%.

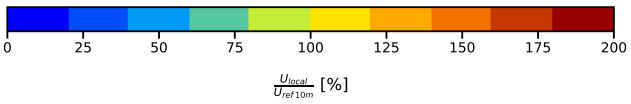
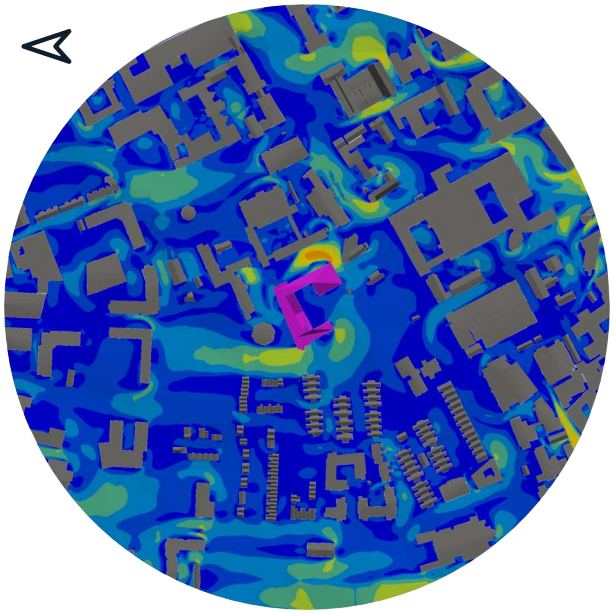
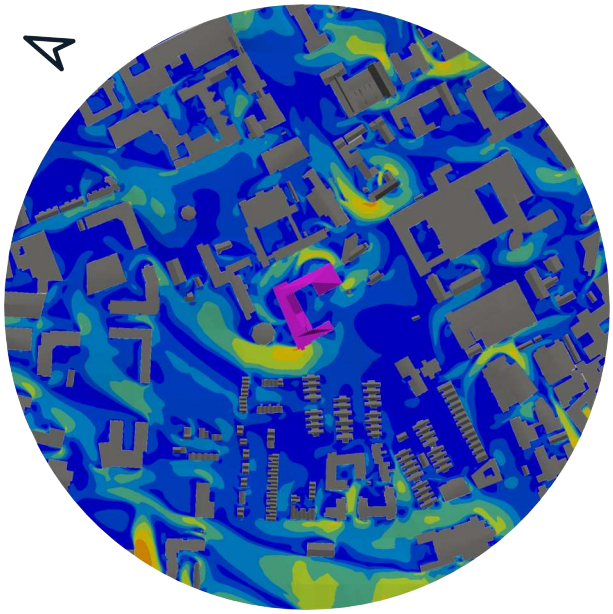


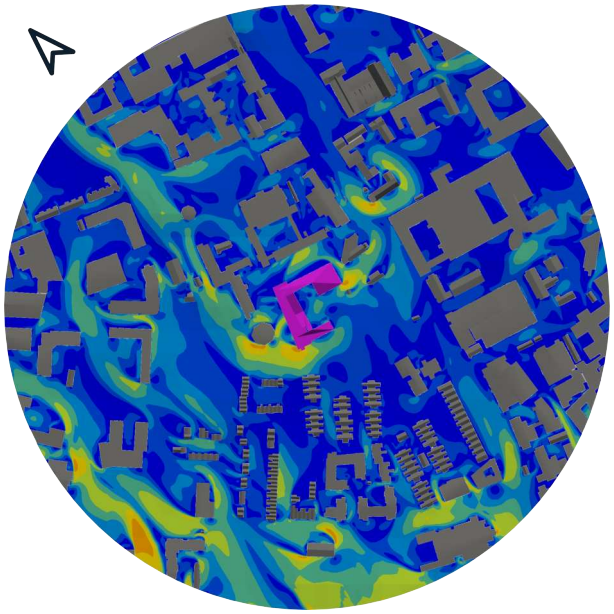
Figure 34: Wind speed scaling factor 1.5 meters above pedestrian-level. The scaling factor shows the local wind speed as a percentage of regional reference wind speed at 10 meters height. Wind directions: 0.0° - 67.5°



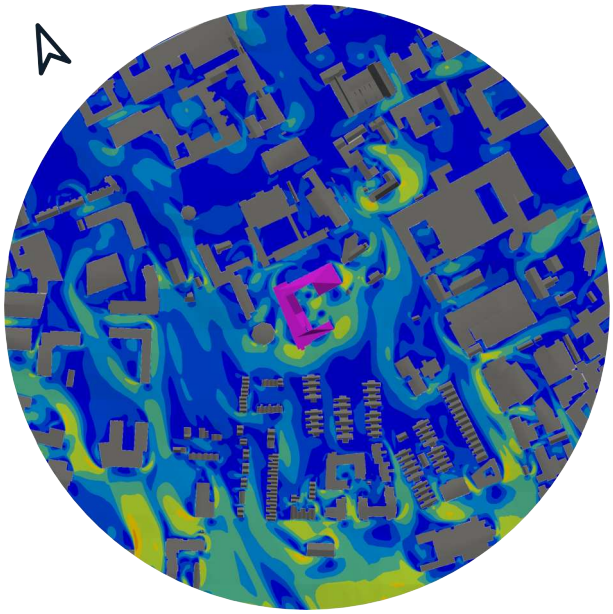
Wind dir: 90.0°. Yearly frequency for sector: 7%.



Wind dir: 112.5°. Yearly frequency for sector: 5%.



Wind dir: 135.0°. Yearly frequency for sector: 5%.



Wind dir: 157.5°. Yearly frequency for sector: 6%.

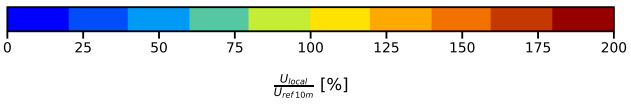
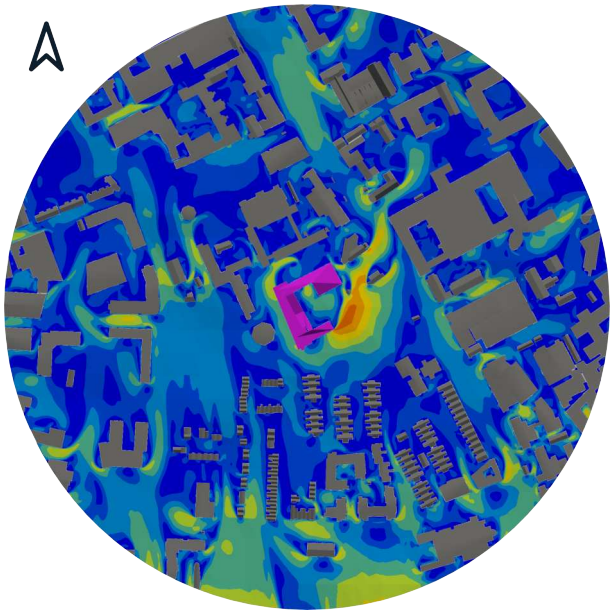
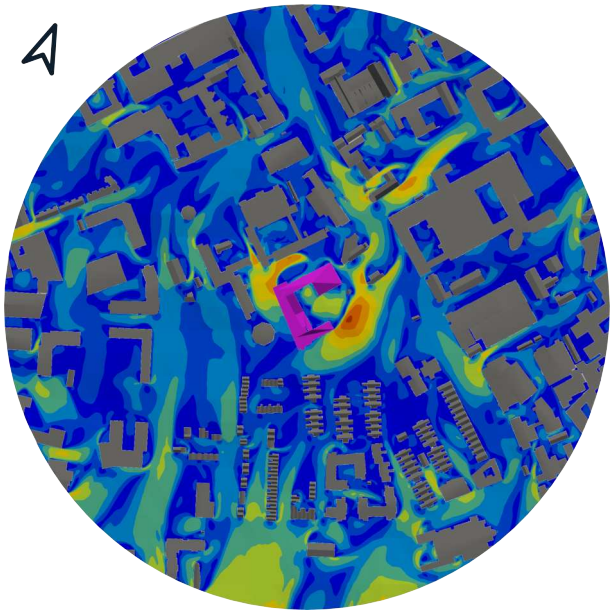


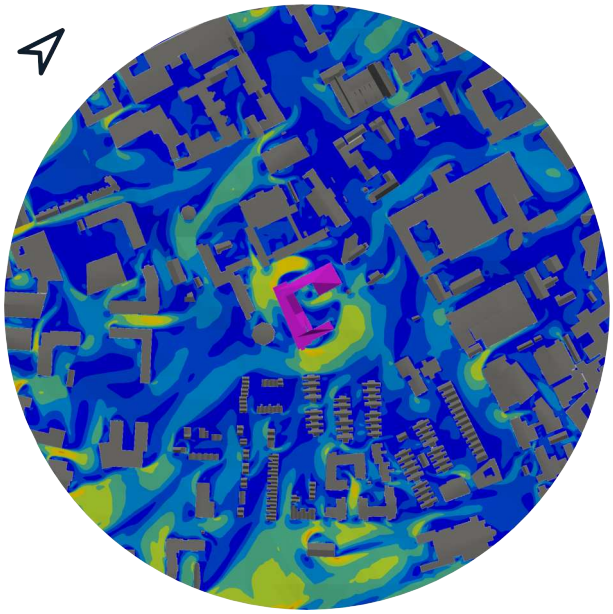
Figure 35: Wind speed scaling factor 1.5 meters above pedestrian-level. The scaling factor shows the local wind speed as a percentage of regional reference wind speed at 10 meters height. Wind directions: 90.0° - 157.5°



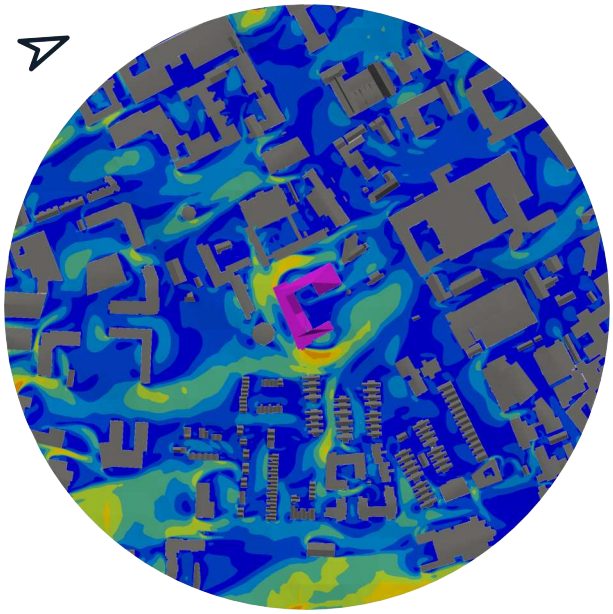
Wind dir: 180.0°. Yearly frequency for sector: 9%.



Wind dir: 202.5°. Yearly frequency for sector: 9%.



Wind dir: 225.0°. Yearly frequency for sector: 9%.



Wind dir: 247.5°. Yearly frequency for sector: 9%.

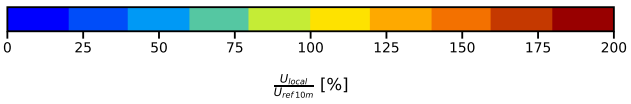
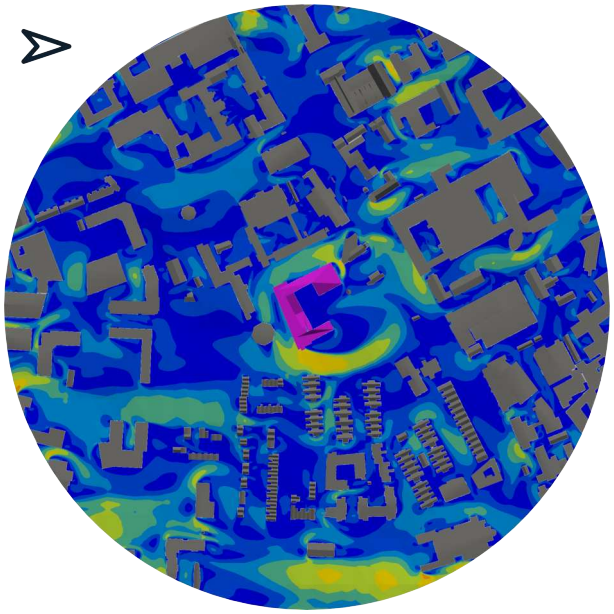
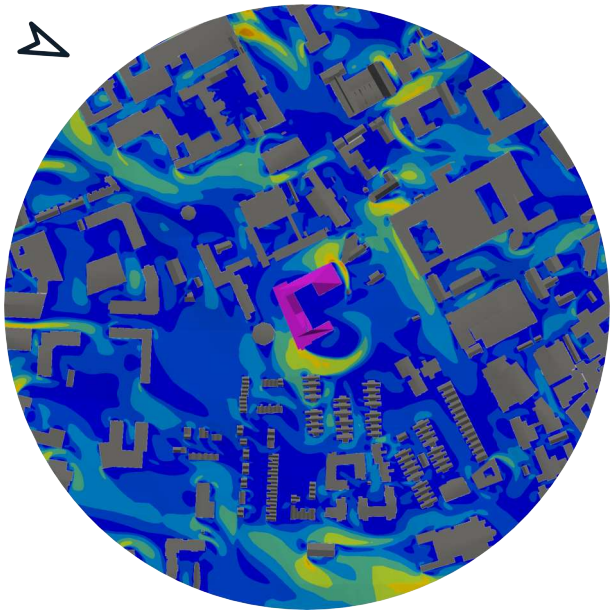


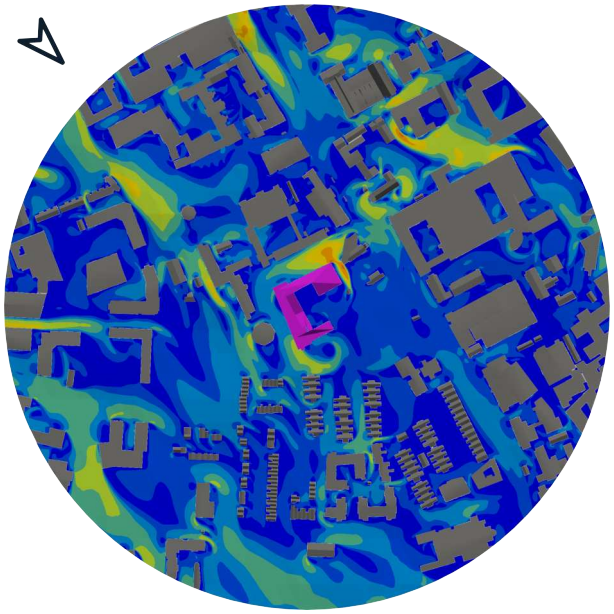
Figure 36: Wind speed scaling factor 1.5 meters above pedestrian-level. The scaling factor shows the local wind speed as a percentage of regional reference wind speed at 10 meters height. Wind directions: 180.0° - 247.5°



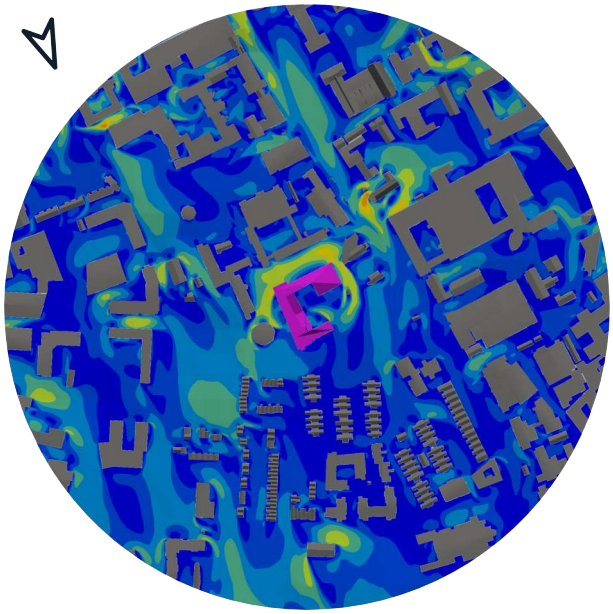
Wind dir: 270.0°. Yearly frequency for sector: 11%.



Wind dir: 292.5°. Yearly frequency for sector: 10%.



Wind dir: 315.0°. Yearly frequency for sector: 5%.



Wind dir: 337.5°. Yearly frequency for sector: 2%.

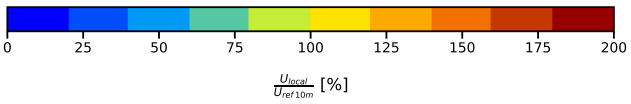
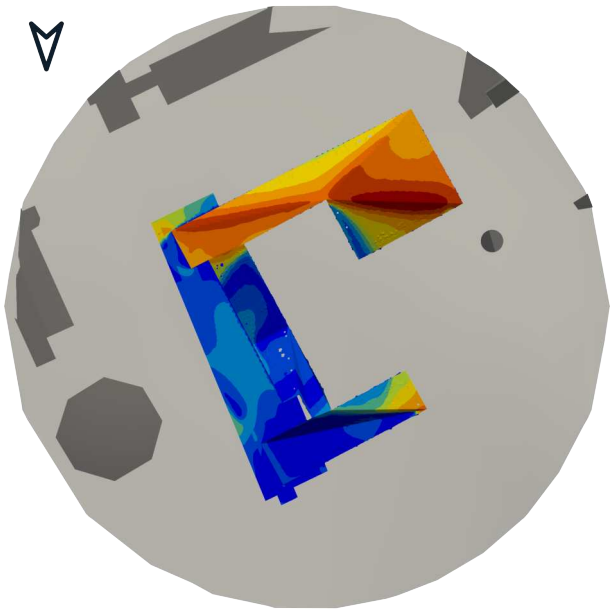


Figure 37: Wind speed scaling factor 1.5 meters above pedestrian-level. The scaling factor shows the local wind speed as a percentage of regional reference wind speed at 10 meters height. Wind directions: 270.0° - 337.5°

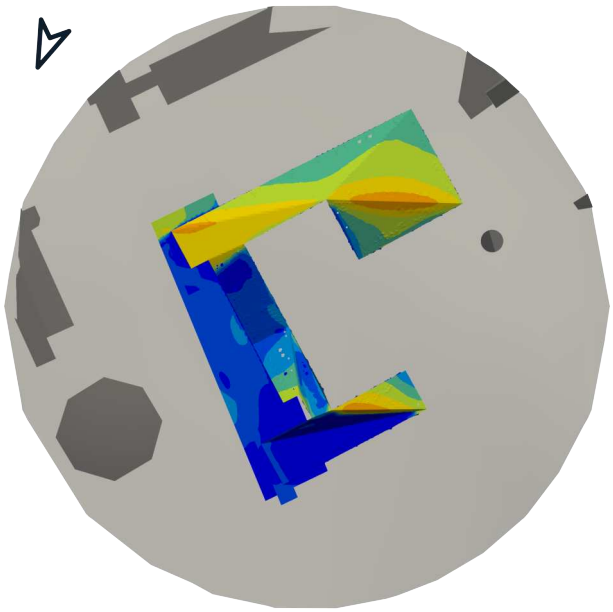
B - Wind speed on buildings

A detailed visualization showing local wind speed over the building mass is presented here.

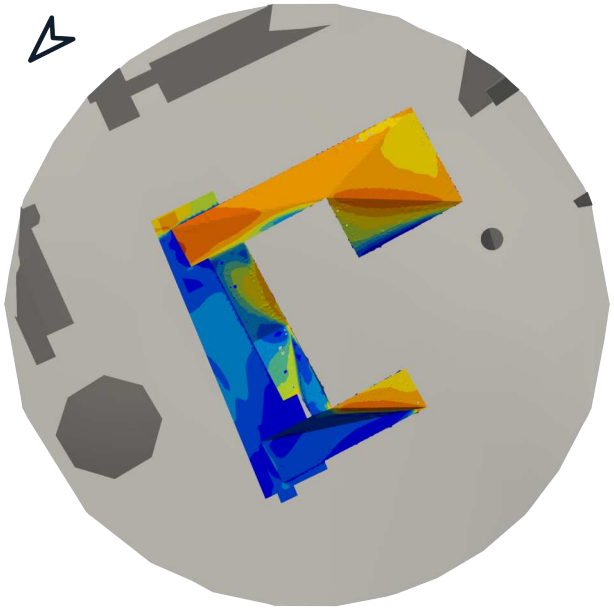
Figure 38, 39, 40 and 41 shows the wind speed scaling factor 1.5 meters above local building height for 16 wind directions. The scaling factor shows the relation between the local wind speed and the regional reference wind speed. In meteorology, wind speed is typically reported at a height of 10 meters above pedestrian-level. Therefore, the reference wind speed (Uref) used in the simulations is also defined as 10 meters above pedestrian-level.



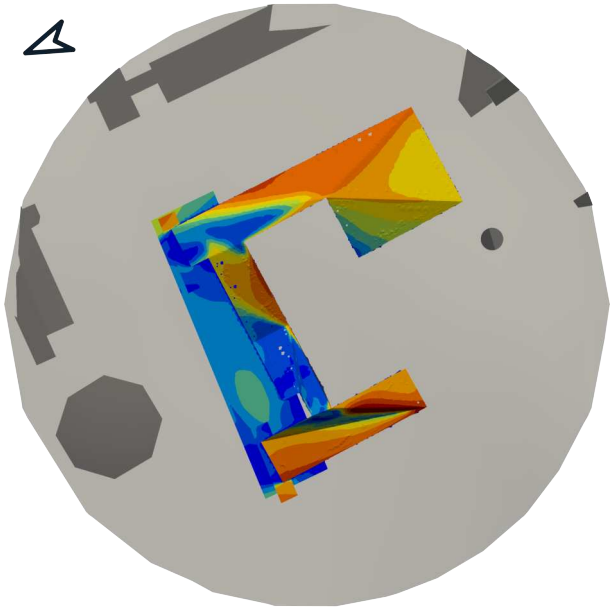
Wind dir: 0.0°. Yearly frequency for sector: 2%.



Wind dir: 22.5°. Yearly frequency for sector: 2%.



Wind dir: 45.0°. Yearly frequency for sector: 4%.



Wind dir: 67.5°. Yearly frequency for sector: 7%.

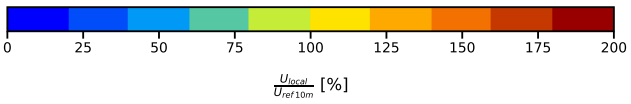
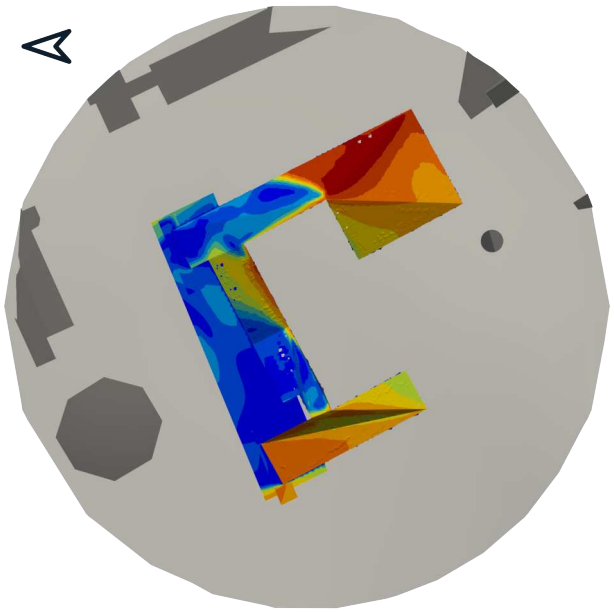
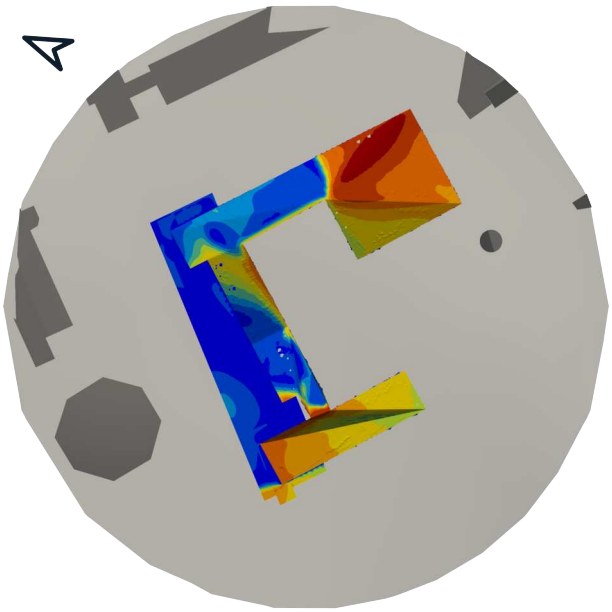


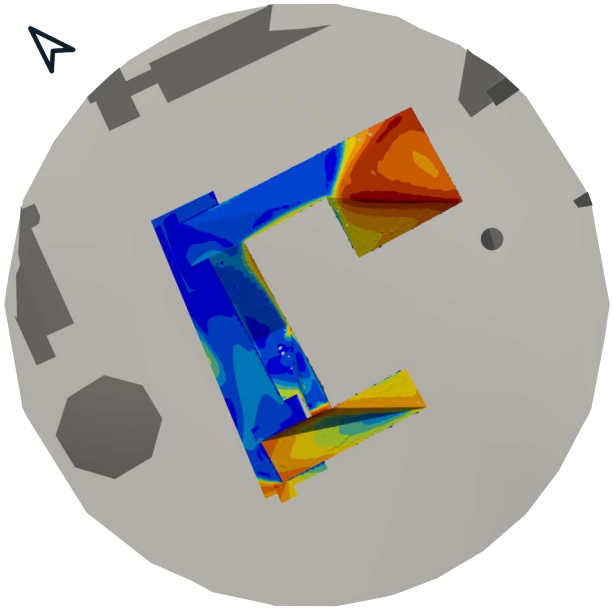
Figure 38: Wind speed scaling factor 1.5 meters above local building height. The scaling factor shows the local wind speed as a percentage of regional reference wind speed at 10 meters height. Wind directions: 0.0° - 67.5°



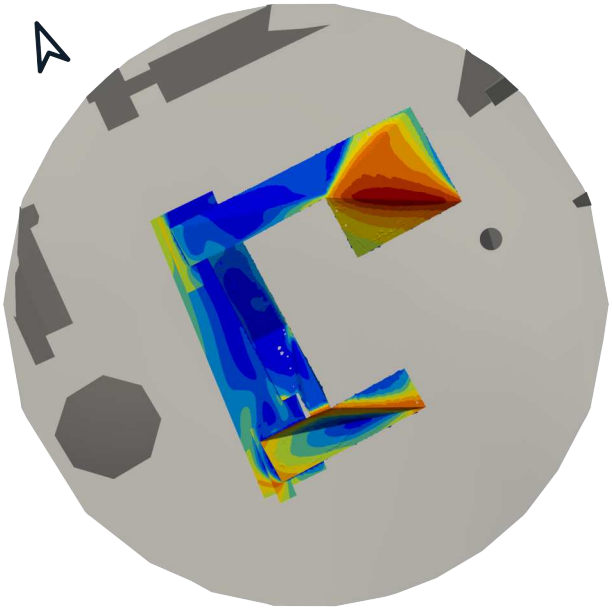
Wind dir: 90.0°. Yearly frequency for sector: 7%.



Wind dir: 112.5°. Yearly frequency for sector: 5%.



Wind dir: 135.0°. Yearly frequency for sector: 5%.



Wind dir: 157.5°. Yearly frequency for sector: 6%.

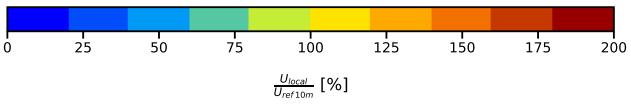
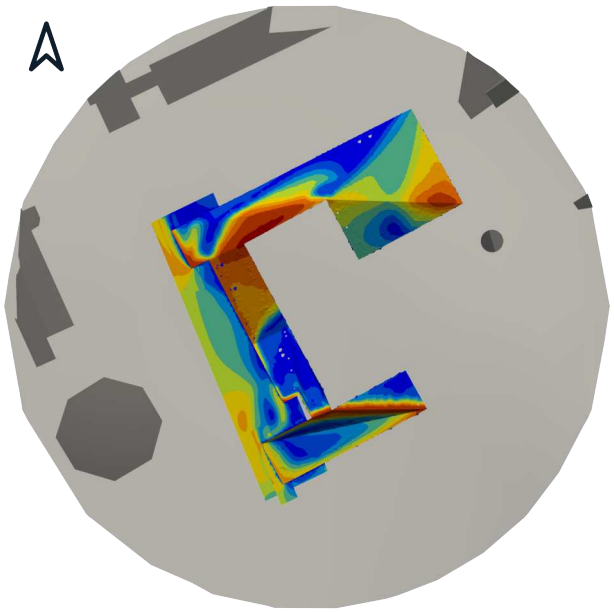
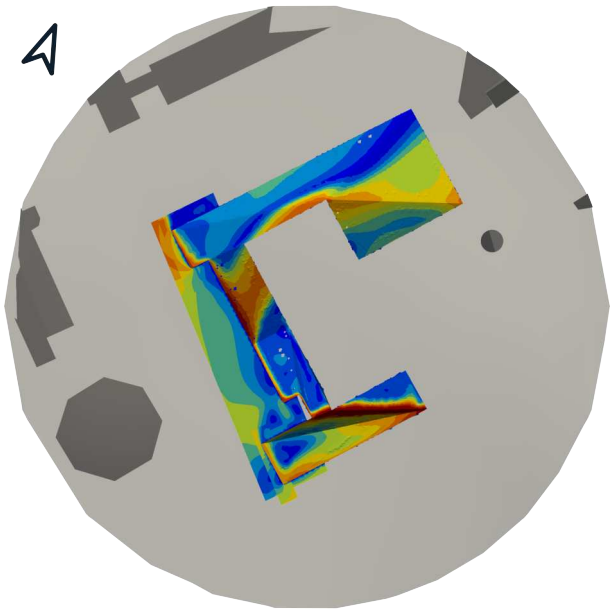


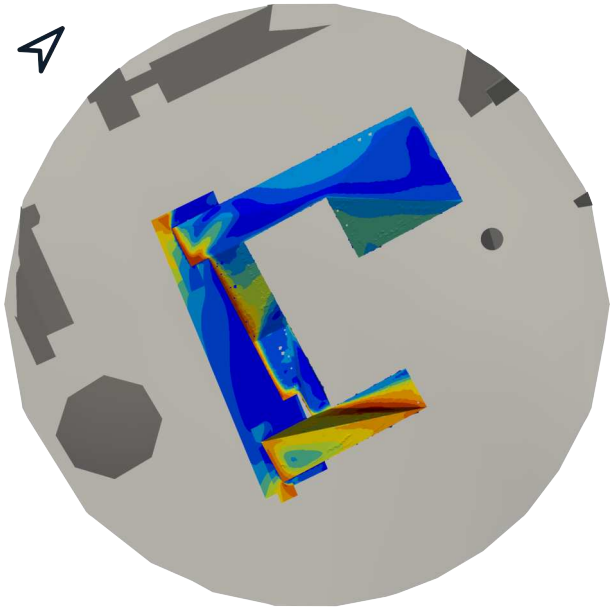
Figure 39: Wind speed scaling factor 1.5 meters above local building height. The scaling factor shows the local wind speed as a percentage of regional reference wind speed at 10 meters height. Wind directions: 90.0° - 157.5°



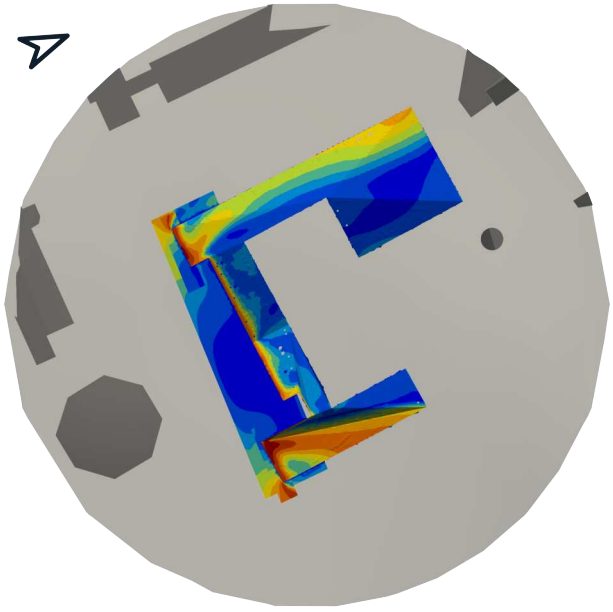
Wind dir: 180.0°. Yearly frequency for sector: 9%.



Wind dir: 202.5°. Yearly frequency for sector: 9%.



Wind dir: 225.0°. Yearly frequency for sector: 9%.



Wind dir: 247.5°. Yearly frequency for sector: 9%.

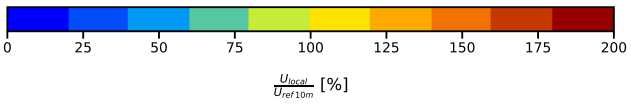
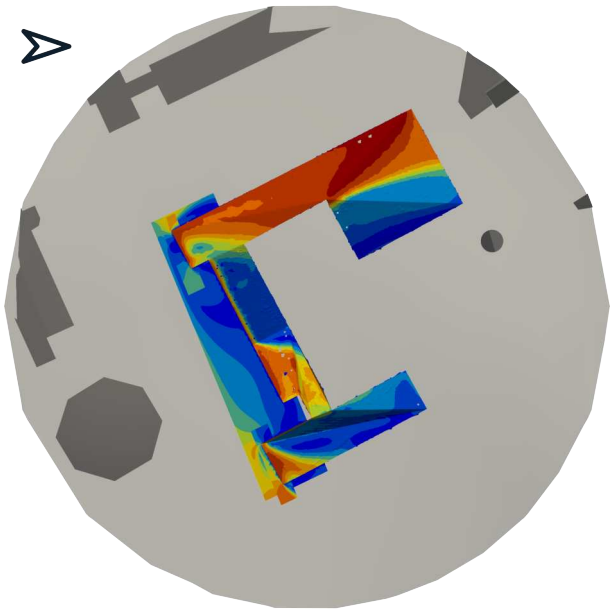
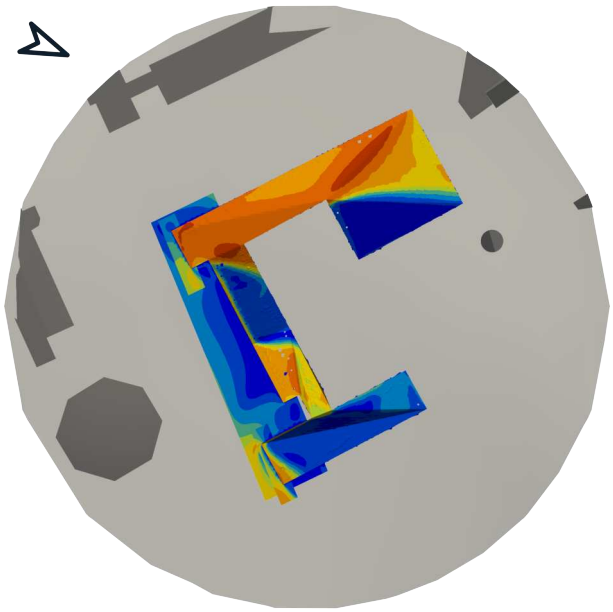


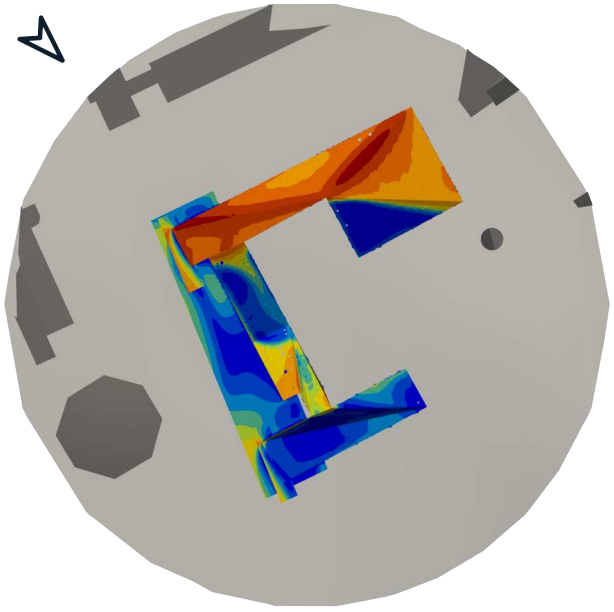
Figure 40: Wind speed scaling factor 1.5 meters above local building height. The scaling factor shows the local wind speed as a percentage of regional reference wind speed at 10 meters height. Wind directions: 180.0° - 247.5°



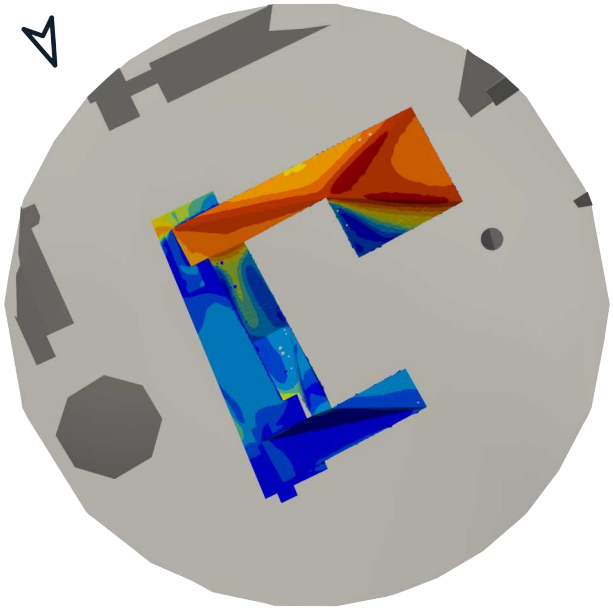
Wind dir: 270.0°. Yearly frequency for sector: 11%.



Wind dir: 292.5°. Yearly frequency for sector: 10%.



Wind dir: 315.0°. Yearly frequency for sector: 5%.



Wind dir: 337.5°. Yearly frequency for sector: 2%.

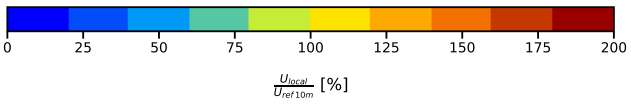
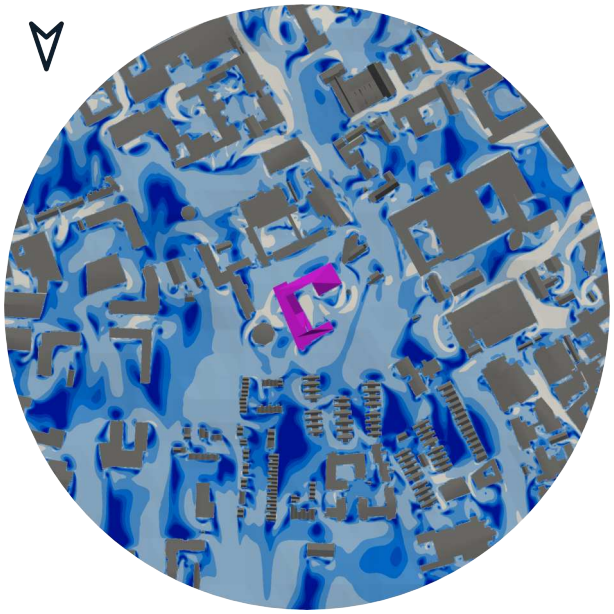


Figure 41: Wind speed scaling factor 1.5 meters above local building height. The scaling factor shows the local wind speed as a percentage of regional reference wind speed at 10 meters height. Wind directions: 270.0° - 337.5°

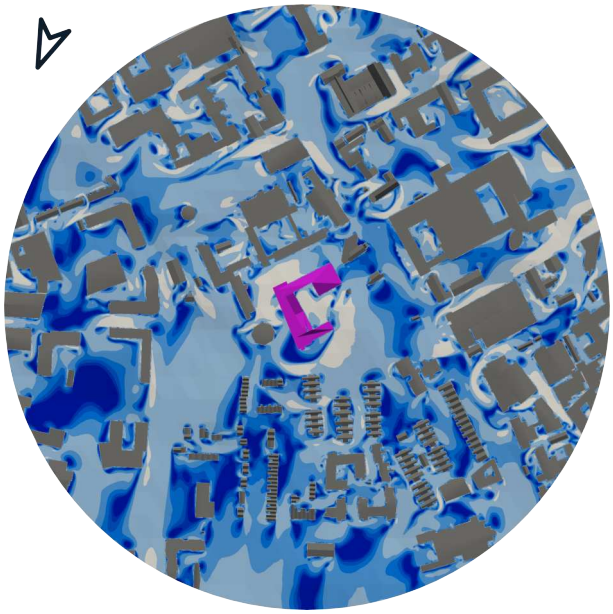
C - Turbulence intensity on terrain

Turbulence intensity for the plan area is shown here. Turbulence intensity does not scale linearly with wind speed and will therefore vary for different wind conditions. Shown here is the turbulence intensity based on a wind speed of 5 m/s at 10 meters height at inlet of the simulation domain.

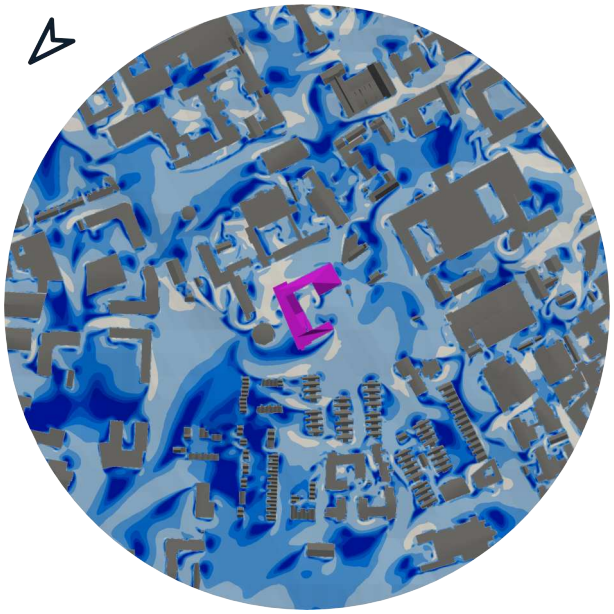
Figure 42, 43, 44 and 45 shows turbulence intensity 1.5 meters above pedestrian-level for 16 wind directions.



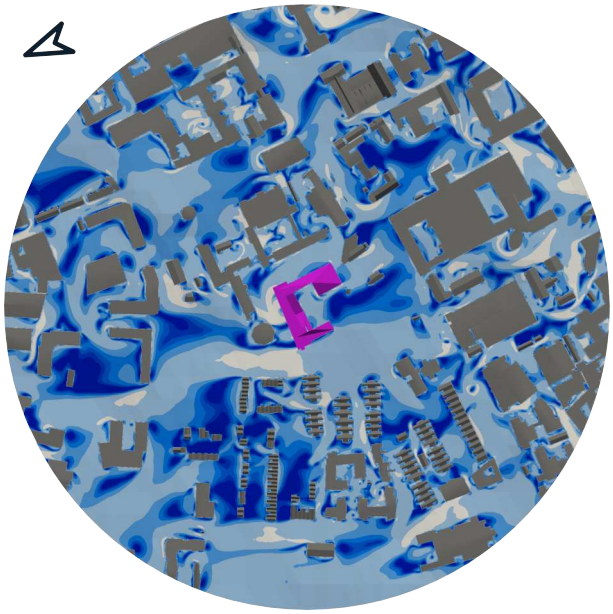
Wind dir: 0.0°. Yearly frequency for sector: 2%.



Wind dir: 22.5°. Yearly frequency for sector: 2%.



Wind dir: 45.0°. Yearly frequency for sector: 4%.



Wind dir: 67.5°. Yearly frequency for sector: 7%.

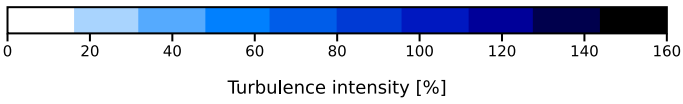
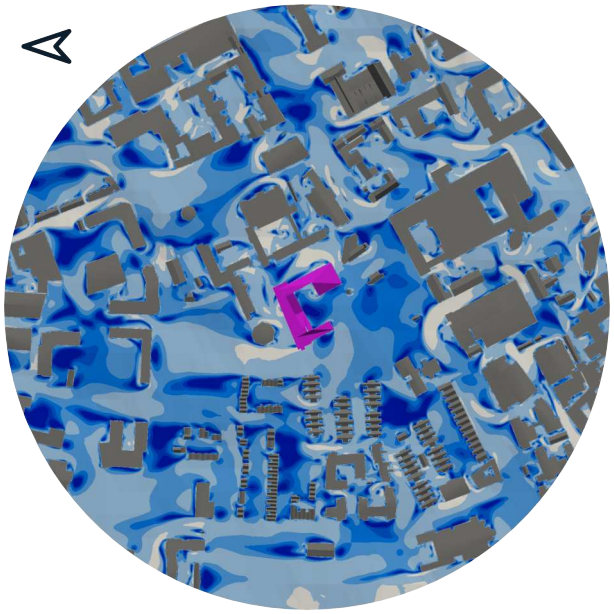
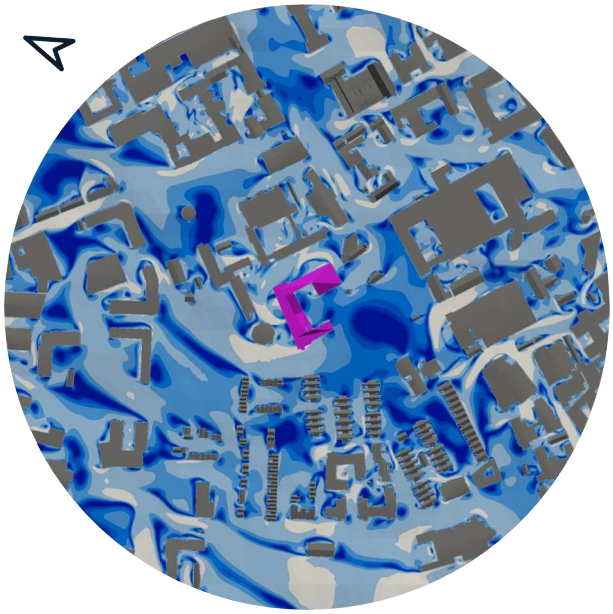


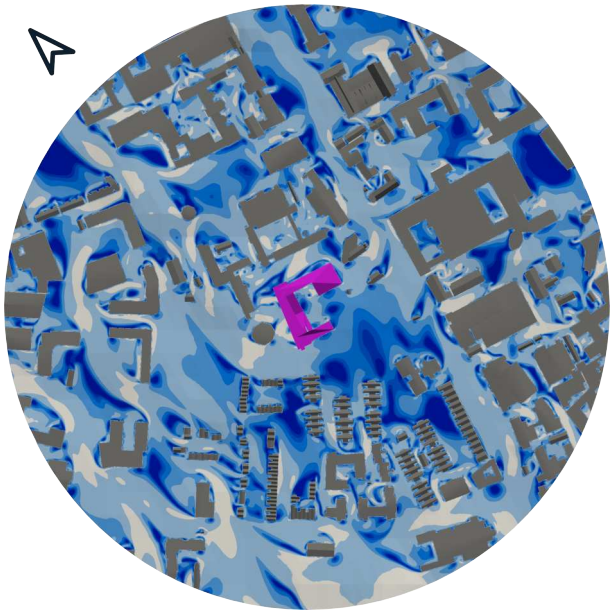
Figure 42: Turbulence intensity 1.5 meters above pedestrian-level. Wind directions: 0.0° - 67.5°



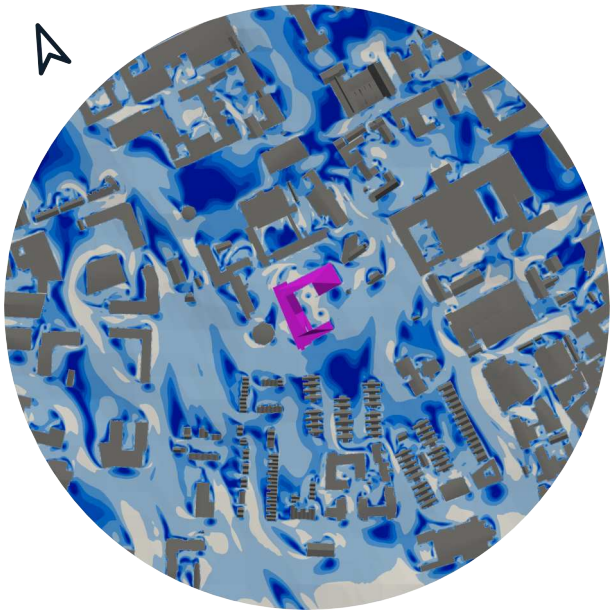
Wind dir: 90.0°. Yearly frequency for sector: 7%.



Wind dir: 112.5°. Yearly frequency for sector: 5%.



Wind dir: 135.0°. Yearly frequency for sector: 5%.



Wind dir: 157.5°. Yearly frequency for sector: 6%.

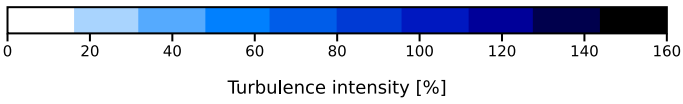
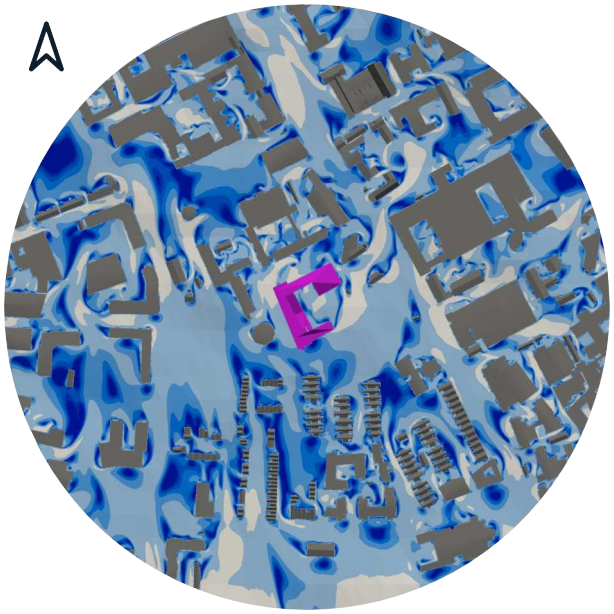
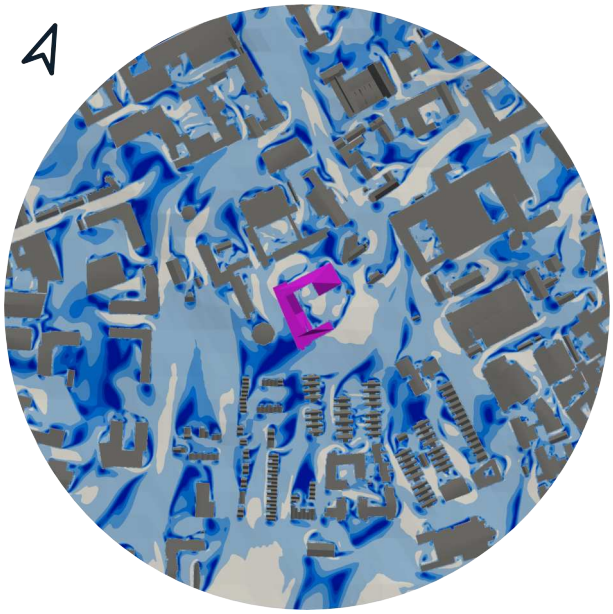


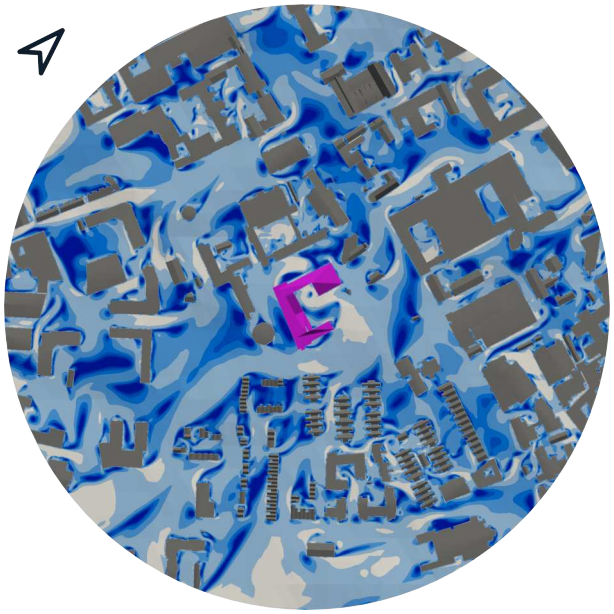
Figure 43: Turbulence intensity 1.5 meters above pedestrian-level. Wind directions: 90.0° - 157.5°



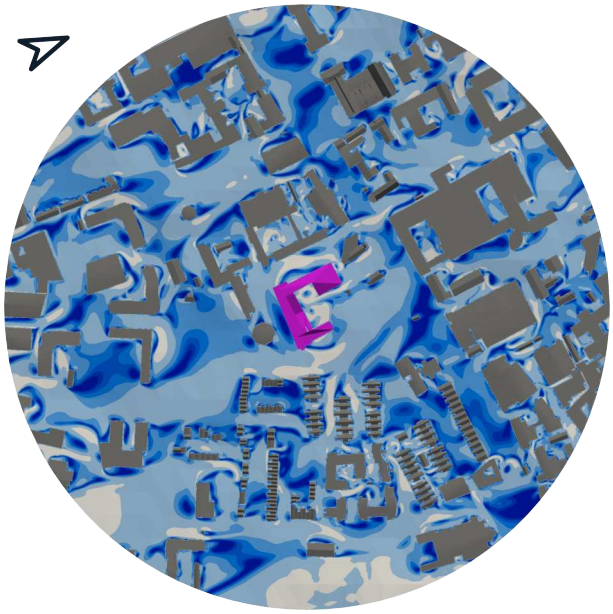
Wind dir: 180.0°. Yearly frequency for sector: 9%.



Wind dir: 202.5°. Yearly frequency for sector: 9%.



Wind dir: 225.0°. Yearly frequency for sector: 9%.



Wind dir: 247.5°. Yearly frequency for sector: 9%.

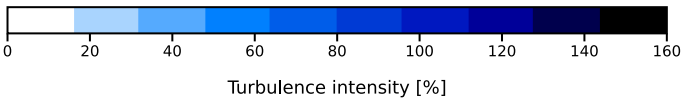
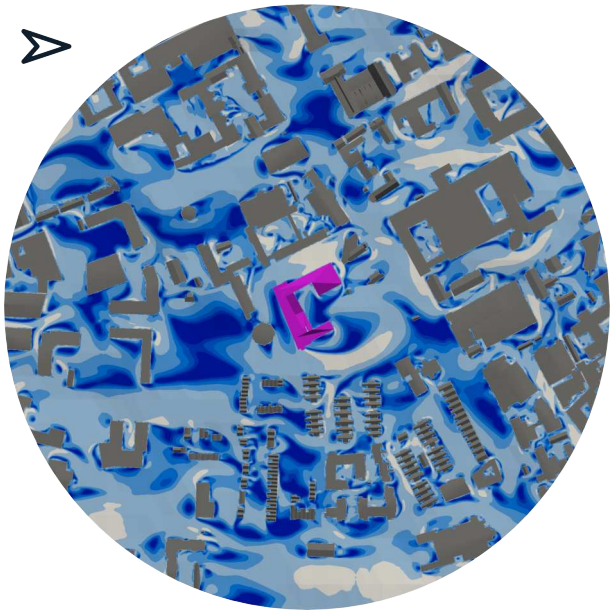
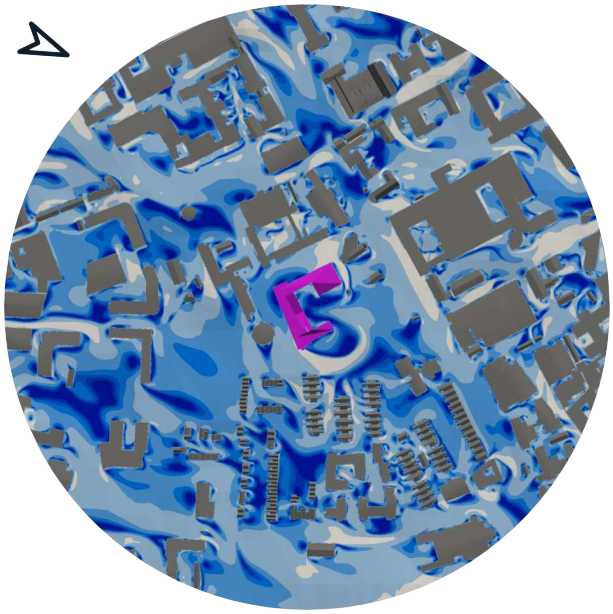


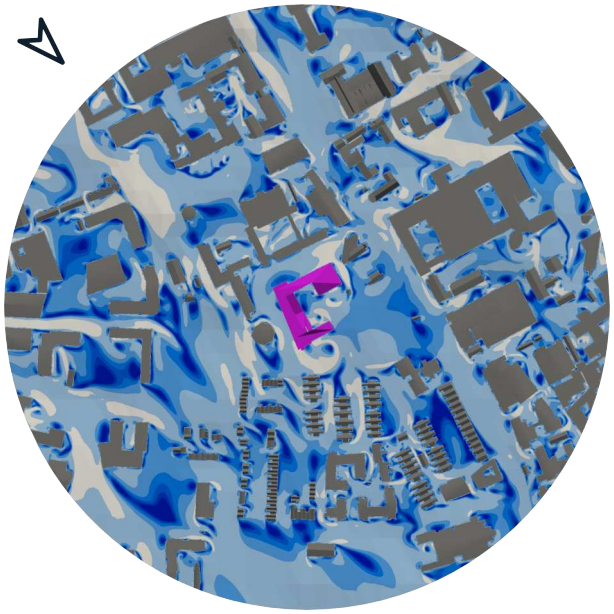
Figure 44: Turbulence intensity 1.5 meters above pedestrian-level. Wind directions: 180.0° - 247.5°



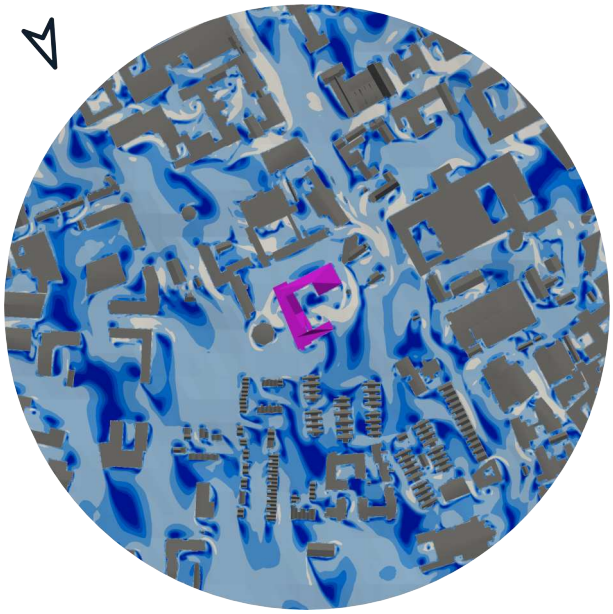
Wind dir: 270.0°. Yearly frequency for sector: 11%.



Wind dir: 292.5°. Yearly frequency for sector: 10%.



Wind dir: 315.0°. Yearly frequency for sector: 5%.



Wind dir: 337.5°. Yearly frequency for sector: 2%.

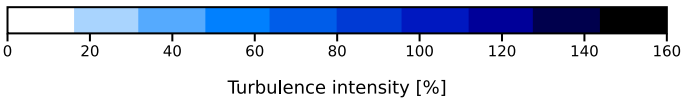


Figure 45: Turbulence intensity 1.5 meters above pedestrian-level. Wind directions: 270.0° - 337.5°