Dolvik, Bergen

Wind Analysis Report

24.03.2022

LINK Arkitektur

Client Data

Client:	In-house report - LINK Arkitektur
Client contact person:	Kari Kløve / Rui Roque Abreu
Client consultant:	Kari Kløve / Rui Roque Abreu
Project leader LINK:	Kari Kløve
Specialists LINK IO:	Mathias Sønderskov Schaltz / Joel Lopez

Table of content

Introduction

Assignment

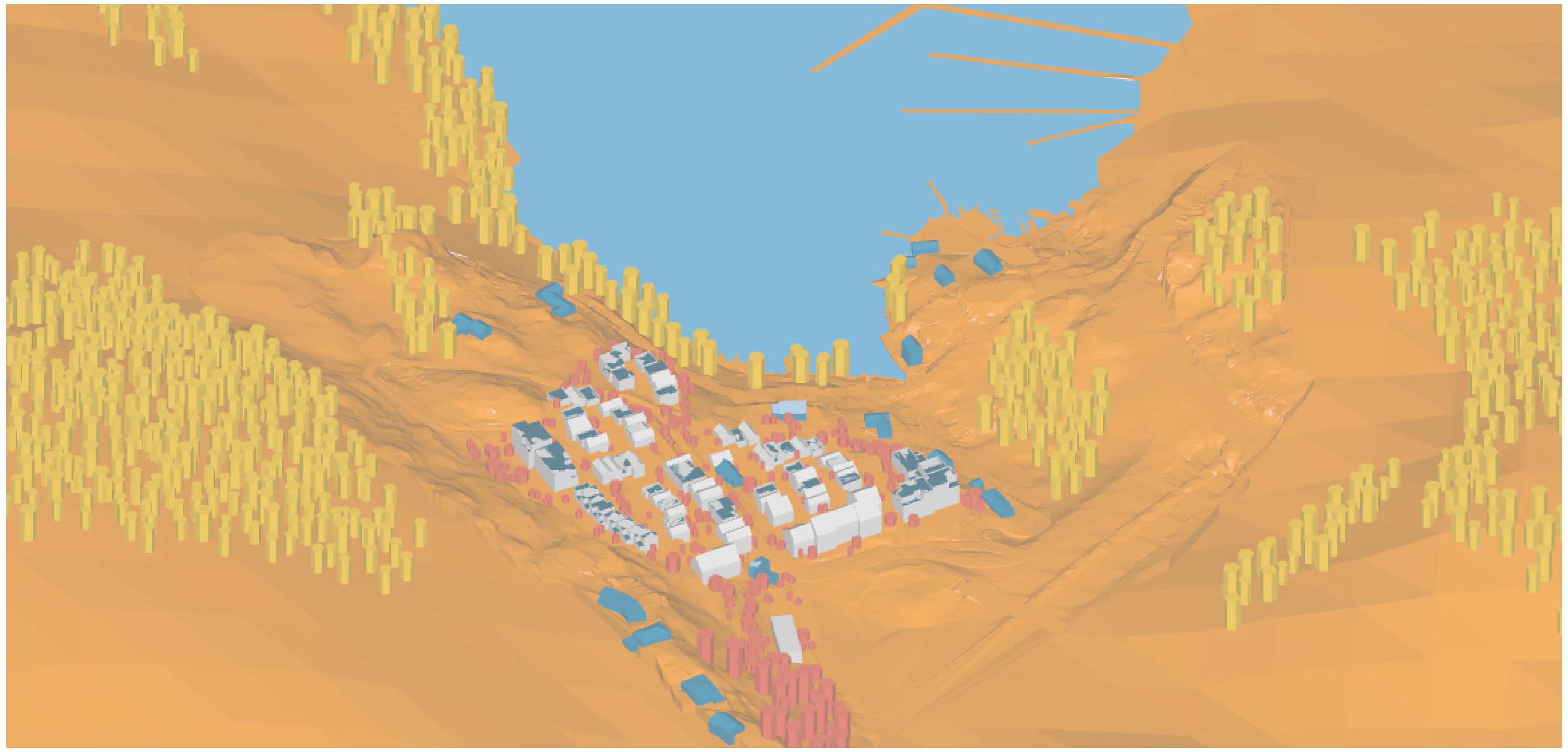
A quantitative wind analysis of the Dolvik project in Bergen has been carried out. The results are based on 3D CFD simulations of the site.
Buildings can have a major impact on the wind. Large facades can "pull down" wind to street level and accelerate the wind field around the corners of the building. Interactions between several buildings that are close together can have unexpected effects on the flow, and streets or open passages through buildings can act as «wind tunnels». These factors can affect the comfort, and in some cases the safety of the area.
Overall, wind conditions around buildings depend on the design of the buildings, their location in relation to each other, the terrain and the wind statistics in the area, factors that are all included in the CFD analysis. The simulation results are used in a calculation of «local wind gain» for all wind directions and a statistical treatment of the results using local meteorological data.
The end product of the analysis is a survey of wind comfort and wind-related safety on the ground floor around the building, according to international standards. The maps for wind comfort and safety address the effect of the flow picture around the buildings, as well as the frequency of wind direction and strength throughout the year.

Local conditions

Location

Dolvik is located in the outskirts of the city of Bergen, about 15.0 km from the city center and about 4.5km from Bergen airport. The site is located very close to a fjord, and the project proposes a new residential area with a variety of typologies and shared spaces intertwined with the nature and surrounding context.

The landscape around Dolvik is very pronounced, with the site being located on a slope towards the fjord. The whole surrounding area consist of sparse suburban area with small constructions and native vegetation. The image at the bottom shows the modelled topography and context for the site.

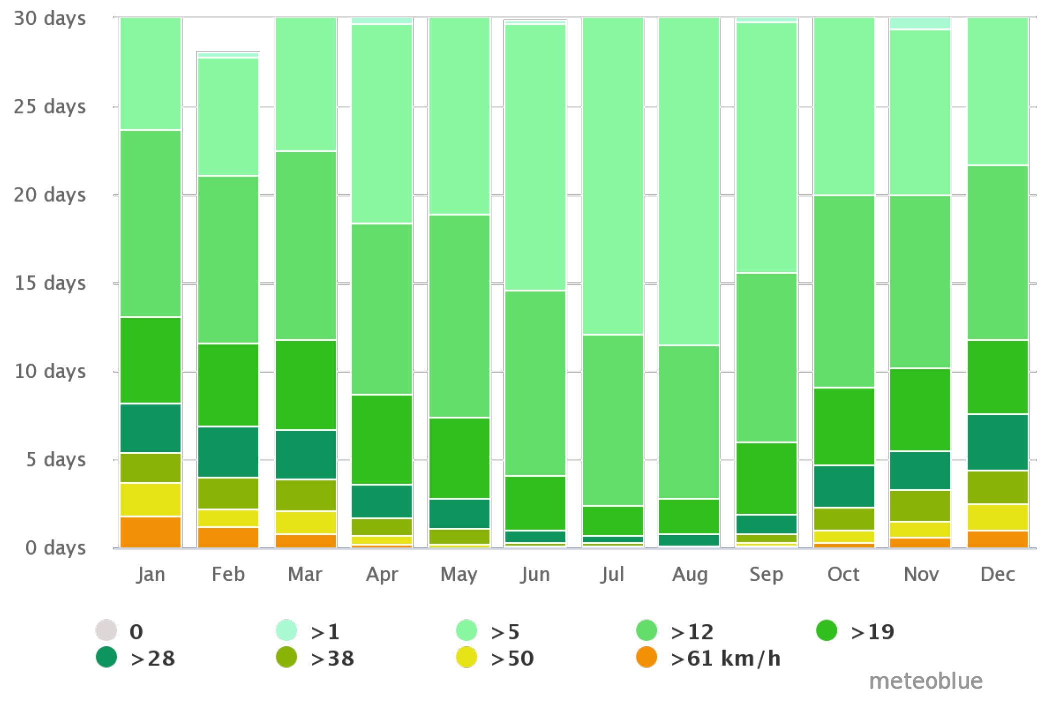


Local conditions

Wind statistics (Meteorological data)

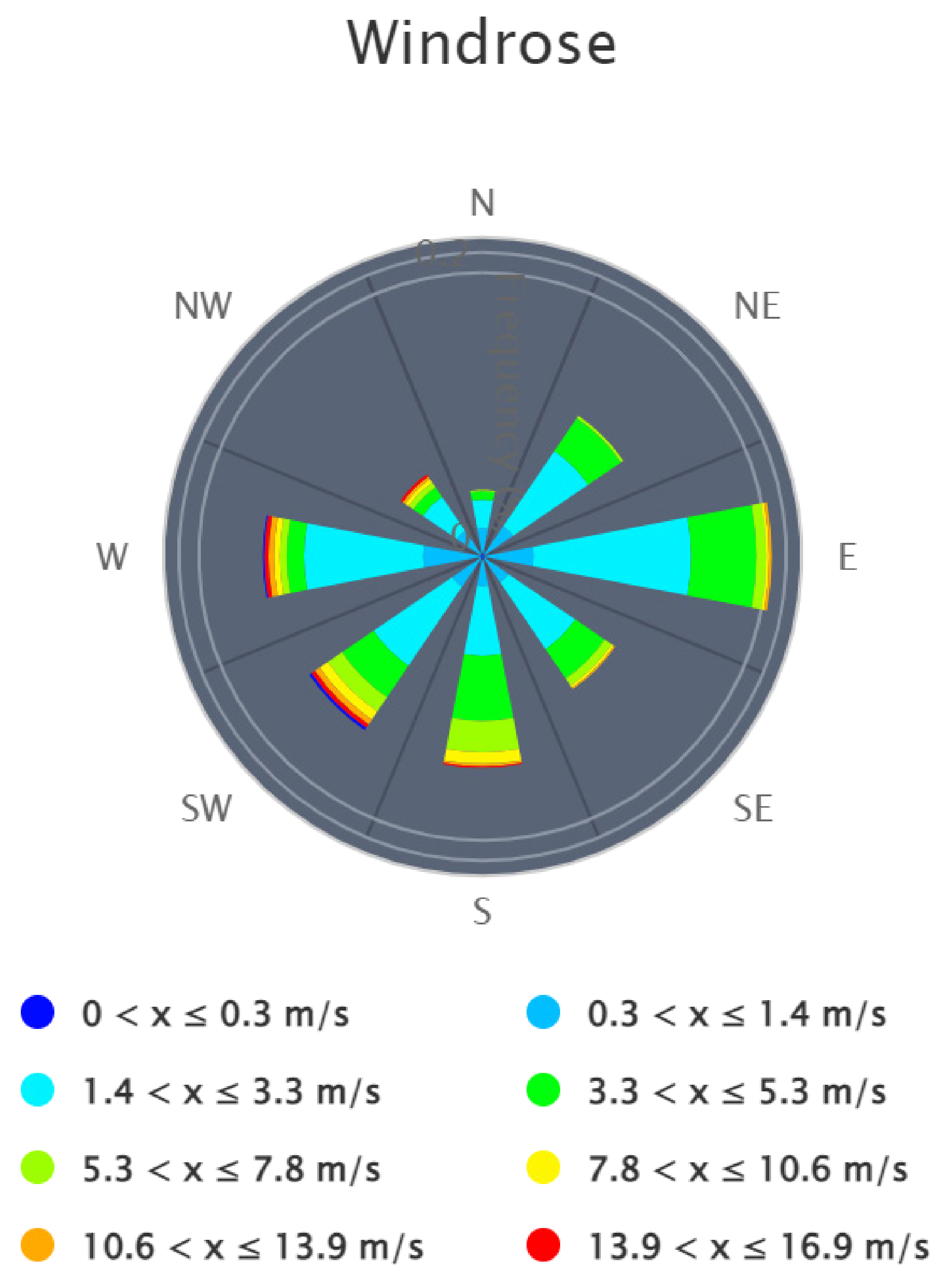
Wind data from METEOBLUE
Dolvik, Bergen, Norway
Latitude: 60.310799
Longitude: 5.263873

General information
Since 2007, Meteoblue has been archiving weather model data. In 2014 they started to calculate weather models with historical data from 1985 onwards and generated a continuous 30-year global history with hourly weather data. The climate diagrams are the first simulated climate data-set made public. The weather history covers any place on earth at any given time regardless of availability of weather stations. They give good indications of typical climate patterns and expected conditions (temperature, precipitation, sunshine and wind). The simulated weather data have a spatial resolution of approximately 30 km and may not reproduce all local weather effects, such as thunderstorms, local winds, or tornadoes, and local differences as they occur in urban, mountainous, or coastal areas.



The diagram for Bergen shows the days per month, during which the wind reaches a certain speed.

Wind Rose (8 directions).



The wind rose for Dolvik in Bergen shows how many hours per year the wind blows from the indicated direction. The predominant directions are East, along with South, Southeast and East.

Local conditions

Site and planned building mass

The landscape around the site in Dolvik is relatelively pronounced towards the fjord. The grey buildings are part of the design proposal, the green buildings are the immediate context. The red hexagons represent trees which are part of the design proposal, the yellow hexangons represent trees which form part of the native vegetation on the context, and the orange surface is the modelled topography of the site.

For the simulation, modelled context in a radius of approx. 150m around the planned area was included. The modelled terrain needs to be extended in all directions around the planned area to ensure the correct flow of wind according to the surrounding topography within the simulation. In this case, the total diameter of the simulated area was approx. 3.2km.

Definitions

Computational Fluid Dynamics (CFD)

CFD means Computational Fluid Dynamics, which is the process of mathematically modeling a physical phenomenon involving fluid flow and solving it numerically using computational processes. CFD constitutes the analysis of the movement of fluids (liquid and gases) within boundary conditions.

The software used to perform the simulation is the browser-based platform for CFD analysis SimScale.
SimScale includes a specialized 'Pedestrian Wind Comfort' simulation option. The option applies a solver based on the Lattice Boltzmann method (LBM) for fluid simulation.

CFD applied to microclimate analysis

Nowadays, the growing awareness for sustainable, safe, and comfortable urban microclimate associated with the rapid development of accessible flow simulation tools enables civil engineers, urban development project managers, and architects to easily implement wind simulation studies to predict and assess wind conditions from early in the design phase until the documentation stage.

Computational fluid dynamics (CFD) simulations are now being widely used for the prediction and assessment of wind comfort environments and high-rise building aerodynamics. There are various types of wind analysis that can be carried out using CFD. Results from CFD wind simulation are now seen as reliable sources of quantitative and qualitative data and are frequently used to make important design decisions.

In architecture and urban design, we can use CFD for the analysis of microclimate in the built environment with analysis such as Pedestrian Wind Comfort (PWC).

What is Pedestrian Wind Comfort?

Pedestrian wind comfort (PWC) refers to the evaluation of the behaviour of wind throughout urban cityscapes to determine its impacts on pedestrians at the ground level. Among other things, this wind modelling assessment takes into consideration wind effects such as tunnel throttling or vorticity which if not planned beforehand can even be harmful or dangerous to people using or even nearby the affected facilities.

Wind Comfort and Safety

It remains a challenge to draw meaningful results and analysis which inform the design process. The Beaufort Scale is an empirical measurement tool of wind speed, and it is still used today to understand and grasp the direct effect on people at a pedestrian level of a given wind speed which comes from a quantitative analysis such as a PWC simulation.

	Description	**Wind speed 1.5m height (m/s)**	**Effect on people**
Comfort	Calm	0.0 - 0.2	-
	Light air	0.3 - 1.5	No noticeable wind
	Light breeze	1.5 - 3.3	Wind felt on face
Discomfort	Gentle breeze	3.4 - 5.4	Hair disturbed, clothings flaps, newspaper difficult to read
	Moderate breeze	5.5 - 7.9	Raises dust and loose paper, hair disarranged
	Fresh breeze	8.0 - 10.7	Force of wind felt on body, danger of stumbling when entering a windy zone
Increasing Discomfort	Strong breeze	10.8 - 13.8	Umbrellas used with difficulty, hair blown straight, difficulty to walk steadily, sideways wind force about equal to forwards walking force, wind noise on ears unpleasant
	Near gale	13.9 - 17.1	Inconvenience felt when walking
Danger	Gale	17.2 - 20.7	Generally impedes progress, great difficulty with balance in gusts
	Strong gale	> 20.7	People blown over

Table 1. Extended Land Beaufort Scale showing wind effects on people.

Sources

https://www.simscale.com/docs/simwiki/cfd-computational-fluid-dynamics/what-is-cfd-computational-fluid-dynamics/

https://www.simscale.com/blog/2018/05/pedestrian-wind-comfort-validation/

Lawson, T.V. and Penwarden, A.D. (1975). The Effects of Wind on People in the Vicinity of Buildings, In: Proceedings 4th International Conference on Wind Effects on Buildings and Structures, Cambridge University Press, Heathrow, pp. 605–622.

Wind Comfort Criteria: Lawson and NEN 8100

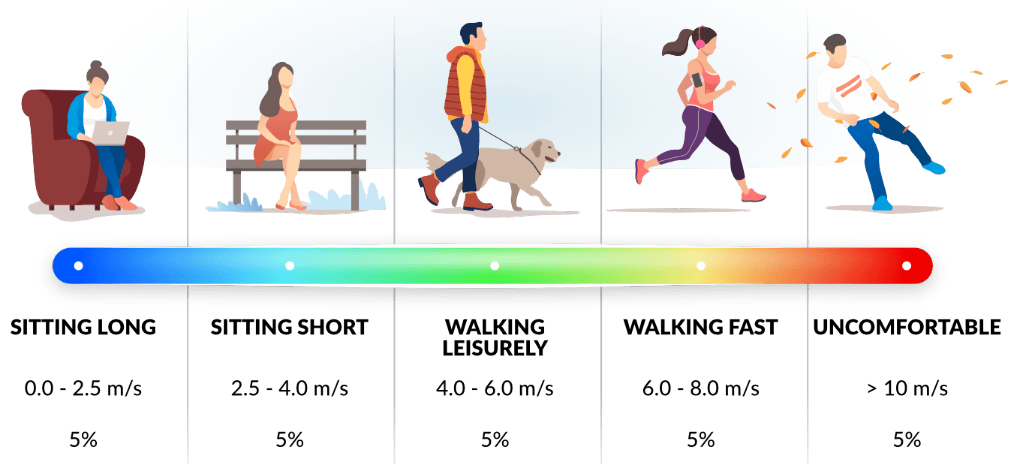
Wind Comfort Criteria
There are many criteria and standards existing today to help assess the expected wind climate in the design stage, by providing parameters of what should be achieved to stay within favourable conditions. In this report, we use the Lawson and NEN 8100 wind criteria.
These criteria are considered comprehensive or complete, as they address a wide range of activities, including “sitting/standing long”, “sitting short” and “strolling”. Both criteria consist of a threshold value of the wind speed and a maximum allowable exceedance probability of this value.

Lawson LDDC Comfort
The Lawson criteria are defined by the probability of one particular location to see wind speed higher than a certain speed. These speeds are measured at a particular height which is usually between 1.5 m and 1.75 m depending on the local authority rules. In simpler terms, the Lawson criteria set threshold wind speeds, and then dictate the probability of wind speeds exceeding that threshold.
The different wind speed threshold values, as well as the probability values, make the level of comfort for pedestrians. They usually correspond to an activity that would be able to be achieved in an acceptable manner, such as sitting, standing, walking fast, etc. The probability is calculated using statistical weather data. This statistical data is obtained from a year-round data collection of wind speed and frequency in 4 to 36 directions.
Starting with the highest threshold speed (the most uncomfortable or unsafe condition), the probability at each specific point is calculated, and if the probability is less than the one stated by the category, then the category velocity range is satisfied (and the wind velocity deemed safe for pedestrians!). The calculation continues with the following threshold speeds until the fulfilment isn’t met anymore, which means the probability is higher than the one set by the category. This means that this specific point has its wind comfort criterion set to the last fulfilled, where the probability was lower than the one set. This computation is made for each point, and for each direction. At each point, and for each direction, the threshold speed is scaled by an amplification factor computed from a combination of CFD results and meteorological data. This meteorological data takes into account the terrain type in each direction; they are associated with a factor value that represents how the wind is slowed down by obstacles like buildings or trees.

General Lawson Criteria
In its original form, Lawson wind comfort criteria are made up of five different categories that all use a probability of 2% as a fulfilment value.
The “Uncomfortable” (red/E) category indicates the most undesired areas, where the value of the speed is higher than 7.6 m/s, is likely to be more than 2% of the time. If such zones are used by pedestrians or cyclists, action should be taken in order to alleviate these unwanted conditions.

The category “Walking Fast”, shown in yellow, corresponds to points where the likelihood of seeing a wind speed higher than 7.6 m/s is likely to be less than 2% of the time. Basically this is true for all lower categories as well. So here the wind requirements of this category are met, but not those of categories A, B, and C. These points would indicate areas of concern depending on the intended use of the area (i.e., an outdoor dining restaurant would not work in these conditions). Typically, there is a threshold (linked again to the local authorities and wind standard) that is a “good quality” if the criteria of the designated usage are met, “acceptable” if it’s one category worse and “unacceptable” if it’s worse two or more categories.
The following categories, shown in green, light blue, and blue, represent points where the speeds higher than 5.3 m/s, 3.6 m/s, 1.8 m/s respectively are less than 2% likely to be observed. These points indicate normal conditions that pedestrians would most likely find comfortable. Under the given activities.

NEN 8100 Criteria
The most recent of these standards is the Dutch wind nuisance standard (NEN 8100), and it applies a discomfort threshold for the hourly mean wind speed of 5 m/s for all types of activities. Depending on the exceedance probability of the threshold wind speed, the code defines three quality classes of wind comfort A–C. This standard also advises on dangers caused by wind.



The figure illustrates the Lawson comfort criteria.

	A	> 1.8 m/s	< 2%	Sitting Long
	B	> 3.6 m/s	< 2%	Sitting Short
	C	> 5.3 m/s	< 2%	Walking Leisurely
	D	> 7.6 m/s	< 2%	Walking Fast
	E	> 7.6 m/s	>= 2%	Uncomfortable

Lawson comfort criteria categories

	A	15 m/s	< 0.05%	No Risk
	B	15 m/s	< 0.30%	Limited Risk
	C	15 m/s	>= 0.30%	Dangerous

NEN 8100 Danger criteria

Sources
https://www.simscale.com/wind-engineering/pedestrian-wind-comfort-wind-modelling/

https://www.simscale.com/blog/2020/01/lawson-wind-comfort-criteria/

https://www.simscale.com/blog/2019/12/wind-comfort-criteria/

Method

Boundary conditions

The CFD simulation in SimScale requires a three-dimensional CAD (computer-aided design) geometry model of the buildings, surrounding context including vegetation, and terrain.

The CAD model is adapted to fit the required fineness for the meshing process of the simulation.

The simulation is performed with the corresponding atmospheric boundary layer, velocity wind profile and turbulence parameters calculated according to the Wind Engineering Standard Eurocode EN 1991-1-4:2005.

This standard requires the specification of the terrain category on each one of the wind directions or exposures the simulation includes in order to assign the value of surface roughness.

Five terrain categories in SimScale correspond to the standard: coastal area (0), flat terrain (I), open terrain (II), suburban (III) and urban (IV). These categories have been assigned according to the surrounding context of the site.

The figure below, illustrates how the shape of the atmospheric boundary layer profile changes with respect to the terrain category.

Simulation Setup

Tasks included:

- Geometry modelling and cleaning
- Simulation setup and run
- Post-processing results

Number of simulations: 1 (Proposal).

Simulation setup, considering area size and resolution needed:

- Wind directions: 8
- Region of interest radius: 150m
- Porous objects included: Trees
- Existing (Selected typology: Chestnut)
- Proposal (Selected typology: Birch)
- Surface roughness factor on terrain: 32.62
- Surface roughness factor on water: 0.00652
- Terrain categories assigned:
- 0.00° (N): Coastal area (0)
- 45.00° (NE): Suburban area (III)
- 90.00° (E): Suburban area (III)
- 135.00° (SE): Suburban area (III)
- 180.00° (S): Suburban area (III)
- 225.00° (SW): Suburban area (III)
- 270.00° (W): Suburban area (III)
- 315.00° (NW): Coastal area (0)
- Results included: Streamliners, Animation.
- Mesh resolution: Coarse (0.59m minimal cell size).

Sources
https://www.simscale.com/docs/analysis-types/pedestrian-wind-comfort-analysis/wind-conditions/atmospheric-boundary-layer/

Method

Evaluation of the Pedestrian Wind Comfort Criteria

To assess a PWC study, three different types of information are needed:
1. Statistical meteorological data
2. Aerodynamic information
3. A comfort criterion

The transformation of the statistical meteorological data to the location of interest at the building site is done through the aerodynamic information, split in two parts:
1. Terrain contribution: Accounts for the change in terrain between the meteorological site and a location near or at the site of the building.
2. Design contribution: Accounts for the change in wind statistics due to local urban configuration.

Understanding this is the basis for the evaluation of pedestrian comfort, to do so, the local wind velocity needs to be related to the weather station data in order to obtain the probability of the local wind speed exceeding the threshold wind speeds defined by the comfort criterion.

The relation between the measured wind speed at the meteorological station umeteo to the local wind speed uloc is defined as the "wind amplification factor":

γ = uloc / umeteo

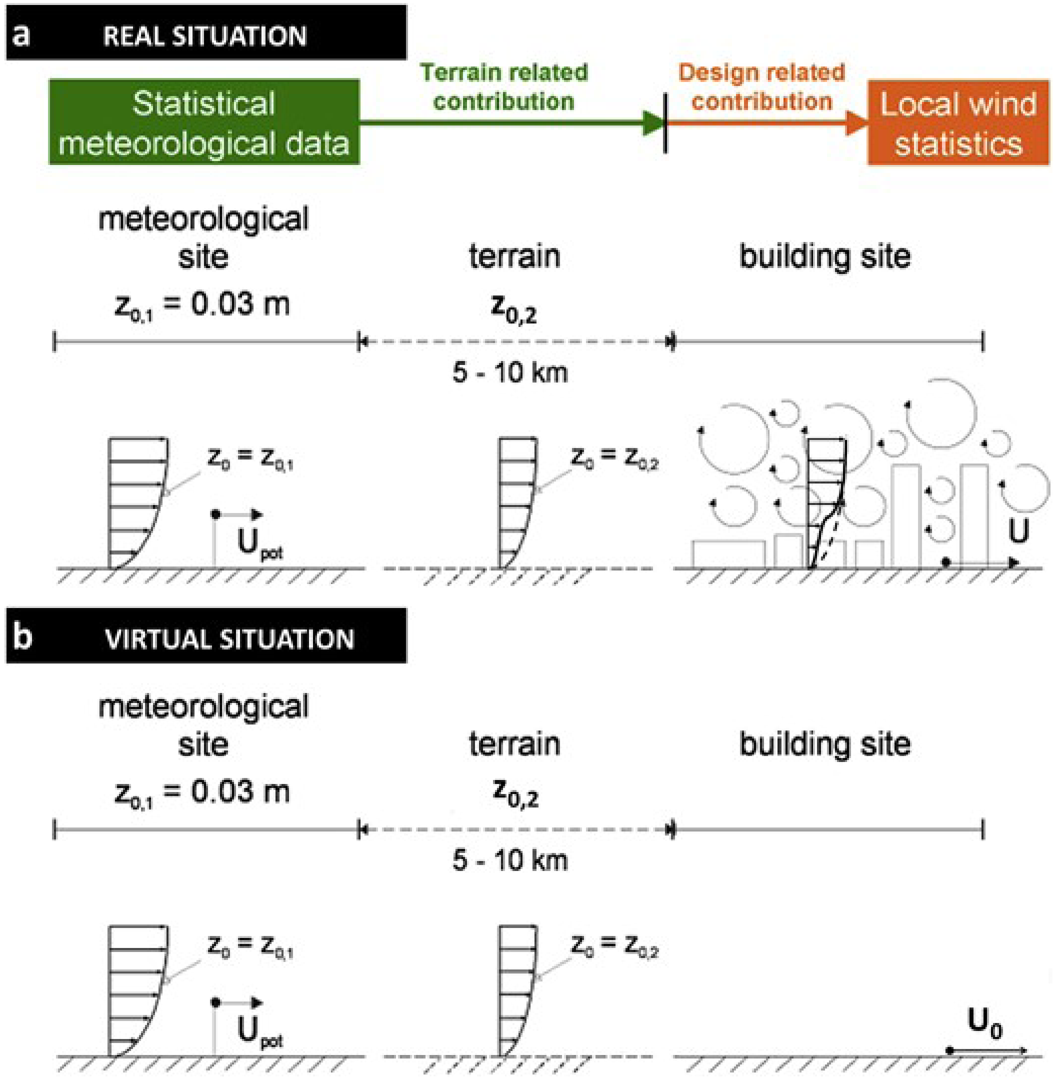
This can be split up in two components:

γ = uloc / umeteo = uloc / u0 * u0 / umeteo

1. uloc / u0 : Local contribution of the topography close to the building (Design contribution of the aerodynamic information; transformation of u0 to uloc).

2. u0 / umeteo : Corrective factor for the weather station wind data. (Terrain contribution of the aerodynamic information; transformation of umeteo to u0).

From the CFD analysis we get the first part ulocu0 directly. However, the correction of the weather station data u0umeteo requires additional effort and calculations, which can differ between each wind engineering standard.

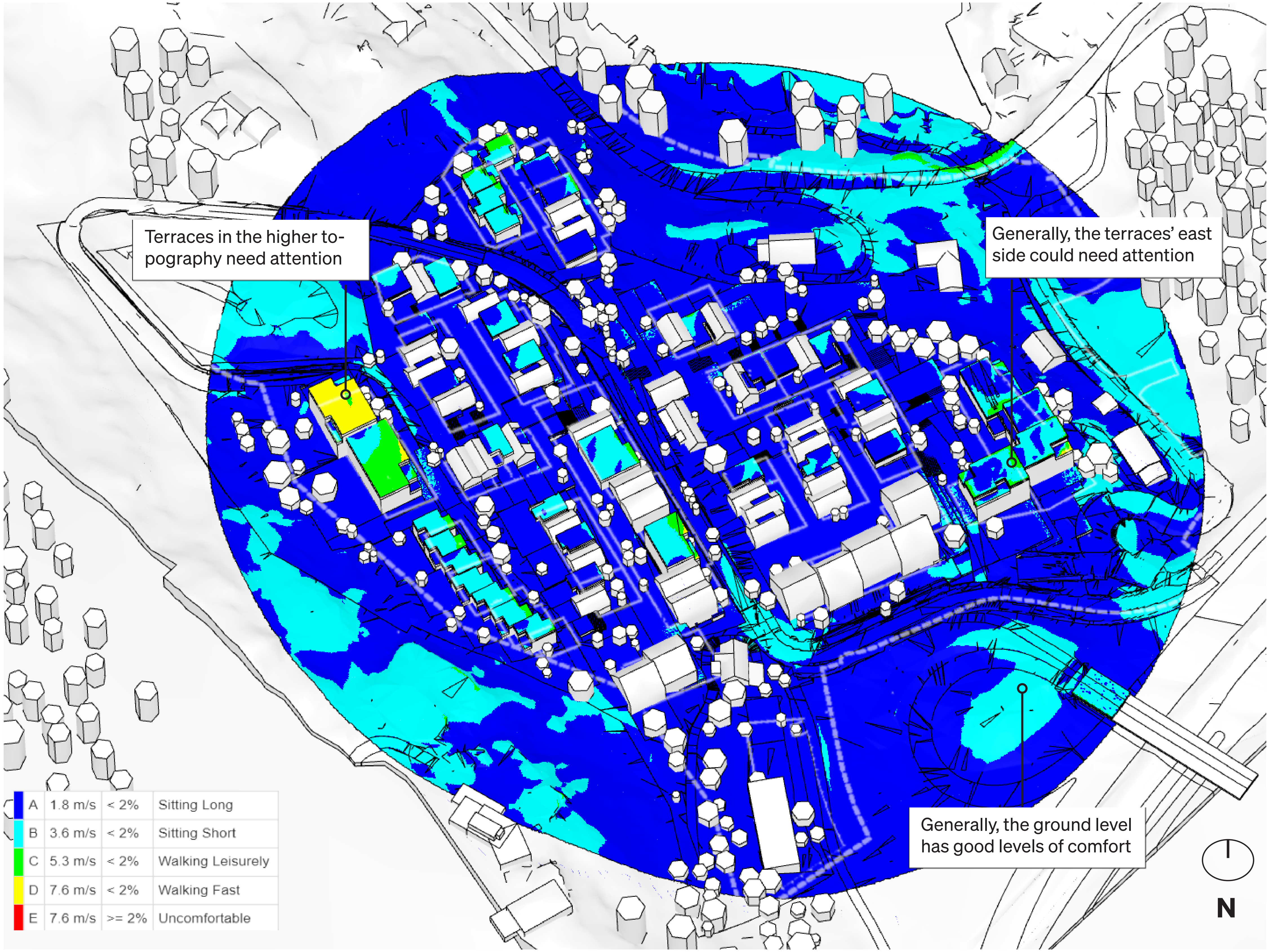


Transformation of the meteorological data at the meteorological site to the building site. (Note: upot refers to umeteo in the figure)

Sources
https://www.simscale.com/docs/analysis-types/pedestrian-wind-comfort-analysis/wind-conditions/atmospheric-boundary-layer/

Pedestrian Comfort Map - Lawson Comfort (Mean Velocity)

Analysis of annual comfort of the whole area at 1.5m above the ground

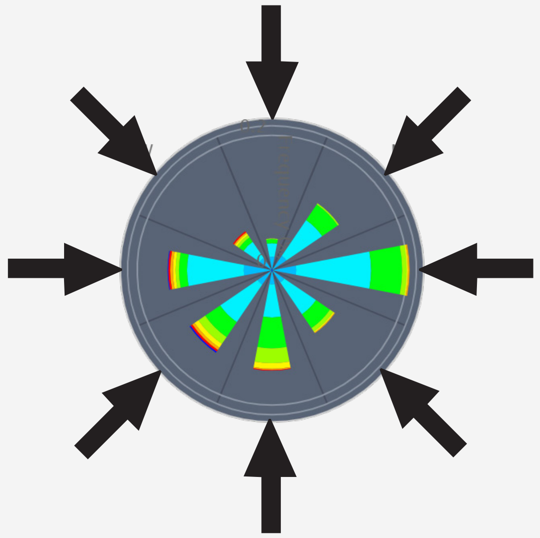


Conclusion

At ground level, most of the area is suitable for sitting long, with some places suitable for sitting short.

Few places with higher speeds than 5.3m/s for 2% of the year.

At terraces level, most of them are suitable for sitting long and short time. Certain terraces might need a design response to improve.

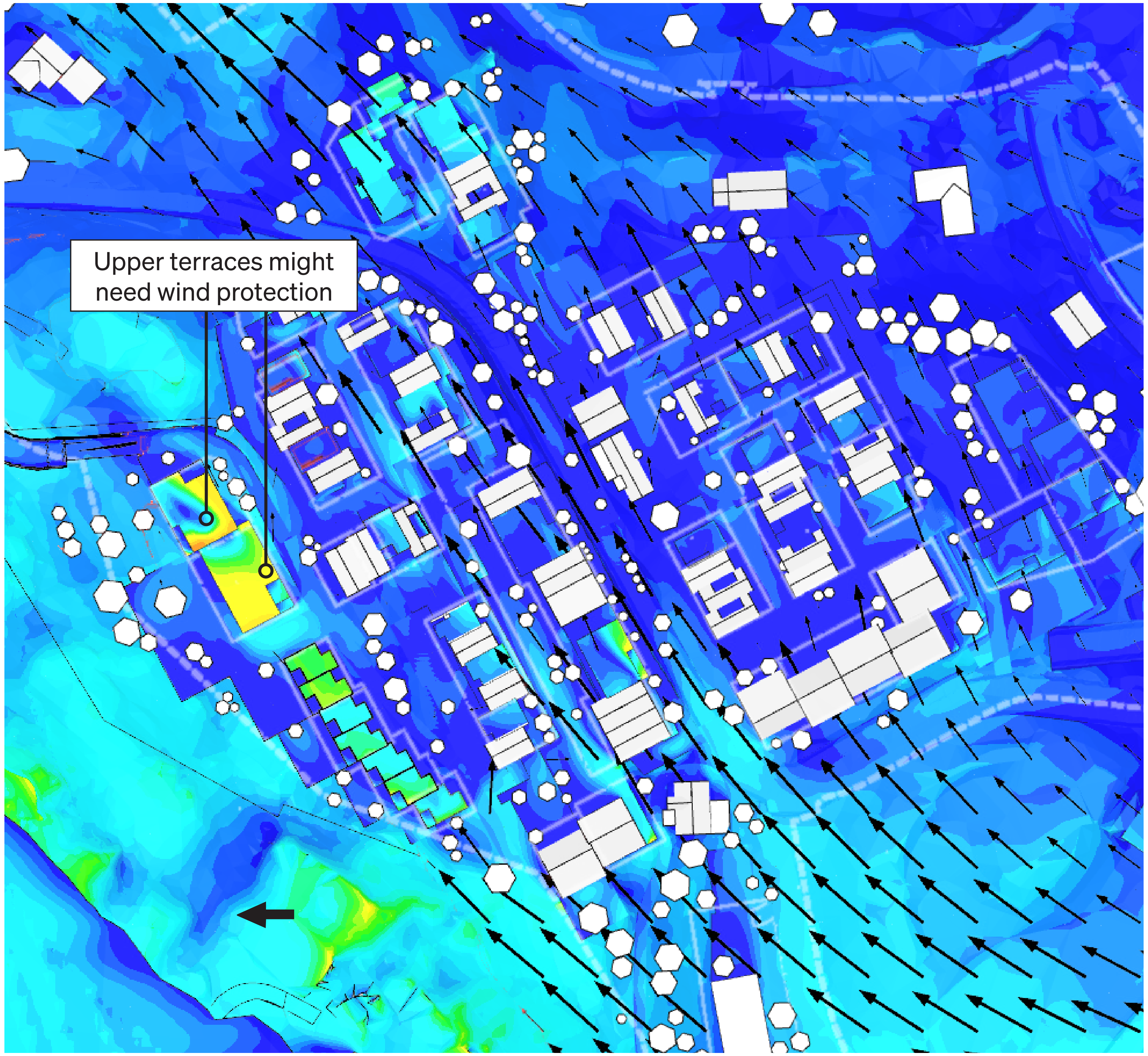


Annual analysis was run on 8 wind directions.

Predominant Winds Analysis: 90°

Wind conditions by each direction at Pedestrian level (1.5m) above the whole surface

90°

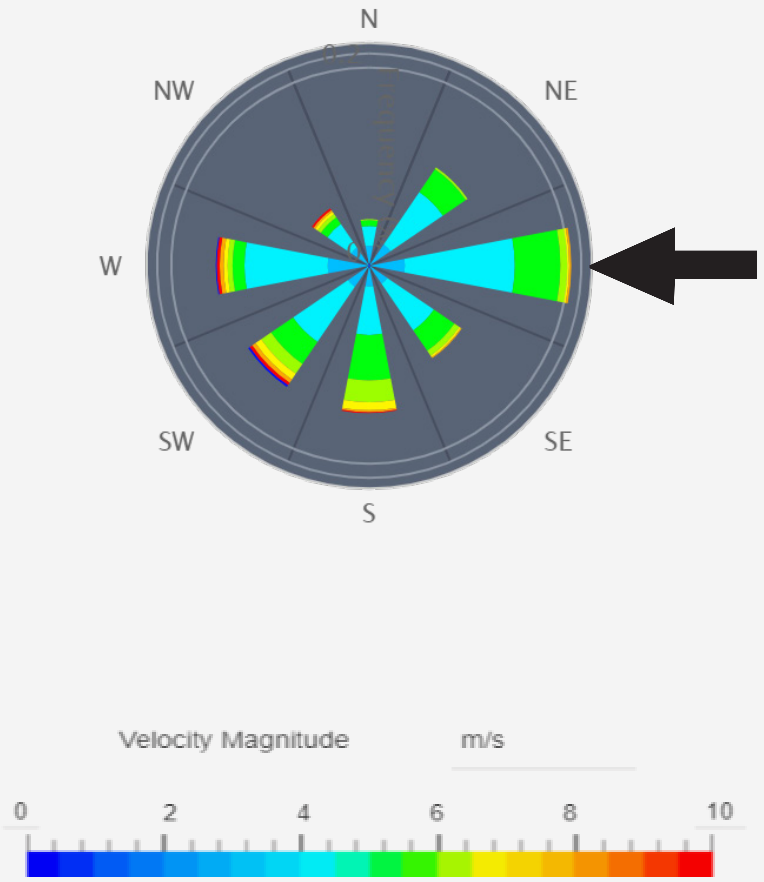


Conclusion

Regarding individual wind direction analysis, the East (90°) and South (180°) direction will have the bigger effect in the proposal, due to the topography and the wind rose for the location.

In the case of the 90° direction, the terraces in higher points in the topography might need design responses to improve comfort. The design response can be composed of wind screens or railings at 1.80 to 2.00m height in the directions of the dominant winds, East and South.

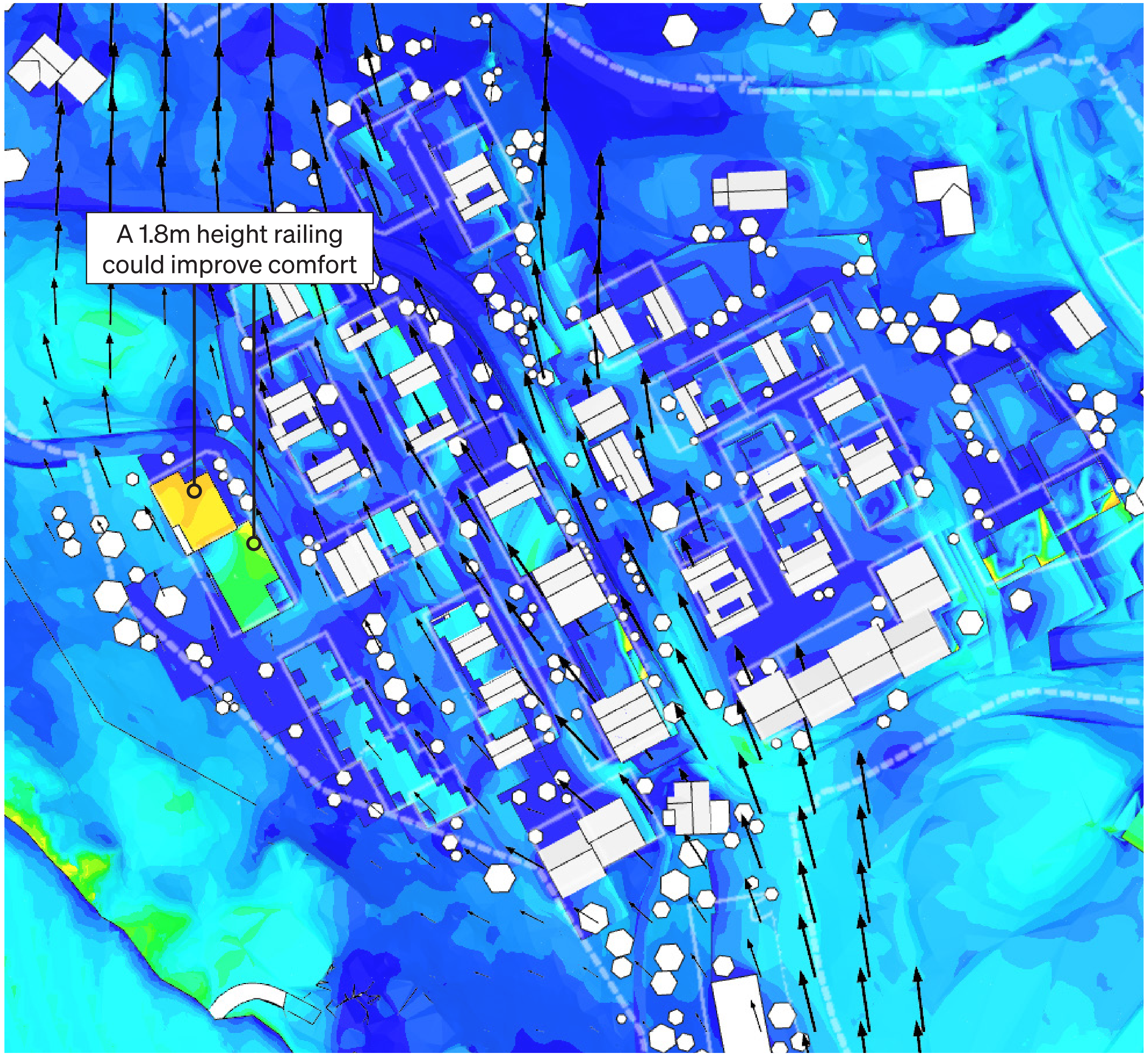
The ground level still performs relatively good in comfort levels regarding the East (90°) wind.



Predominant Winds Analysis: 180°

Wind conditions by each direction at Pedestrian level (1.5m) above the whole surface

180°

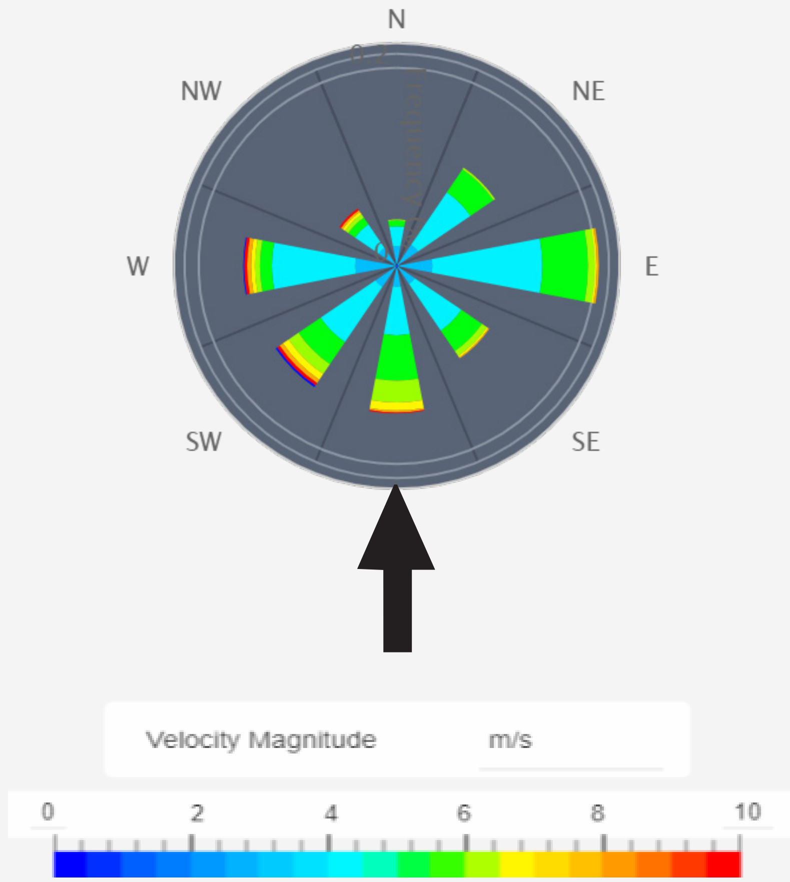


Conclusion

Regarding individual wind direction analysis, the East (90°) and South (180°) direction will have the bigger effect in the proposal, due to the topography and the wind rose for the location.

In the case of the 180° direction, the terraces in higher points in the topography are also affected by this wind direction ,and they might need design responses to improve comfort. The design response can be composed of wind screens or railings at 1.80 to 2.00m height in the directions of the dominant winds, East and South.

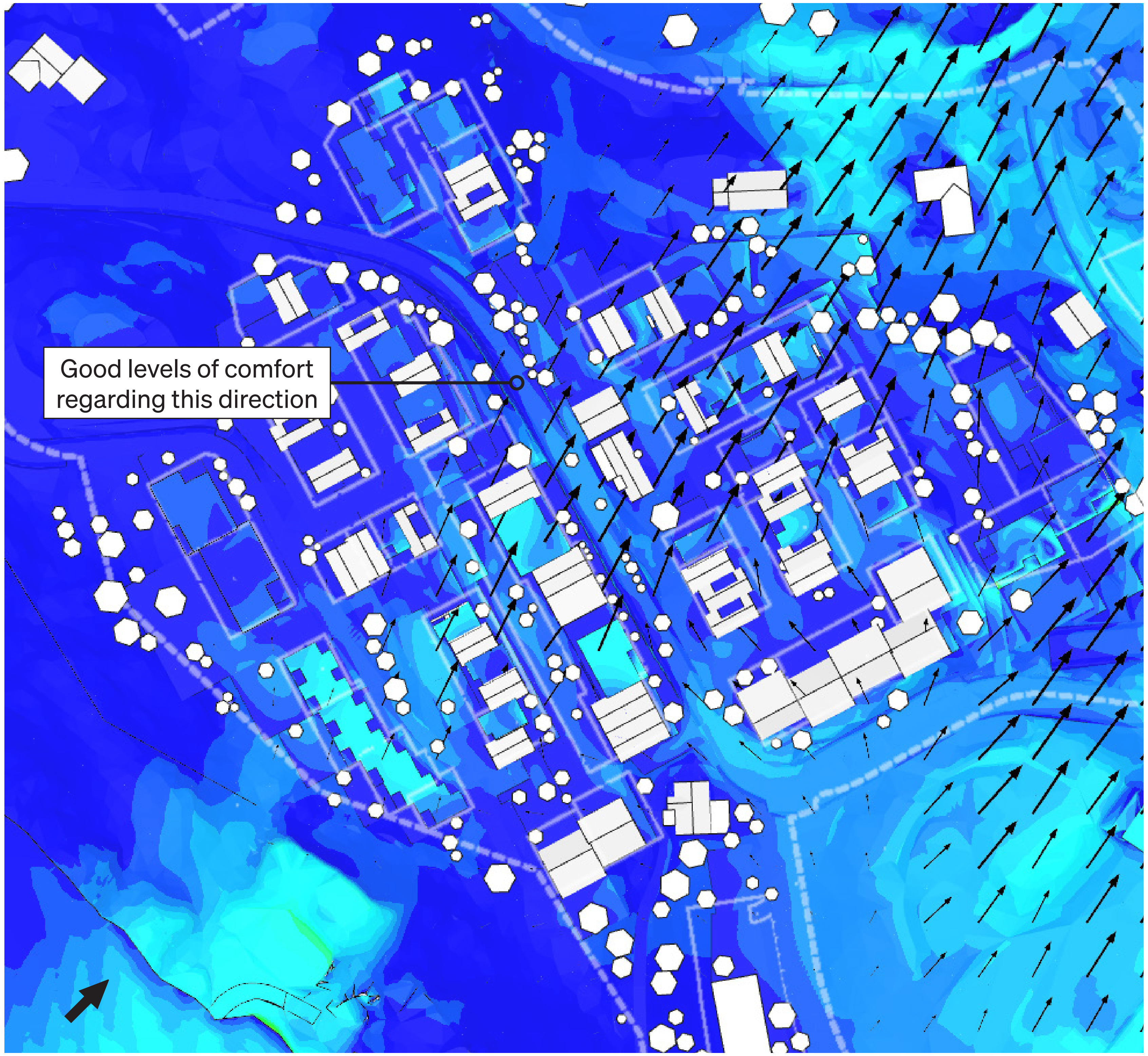
The ground level still performs relatively good in comfort levels regarding the South (180°) wind.



Predominant Winds Analysis: 225°

Wind conditions by each direction at Pedestrian level (1.5m) above the whole surface

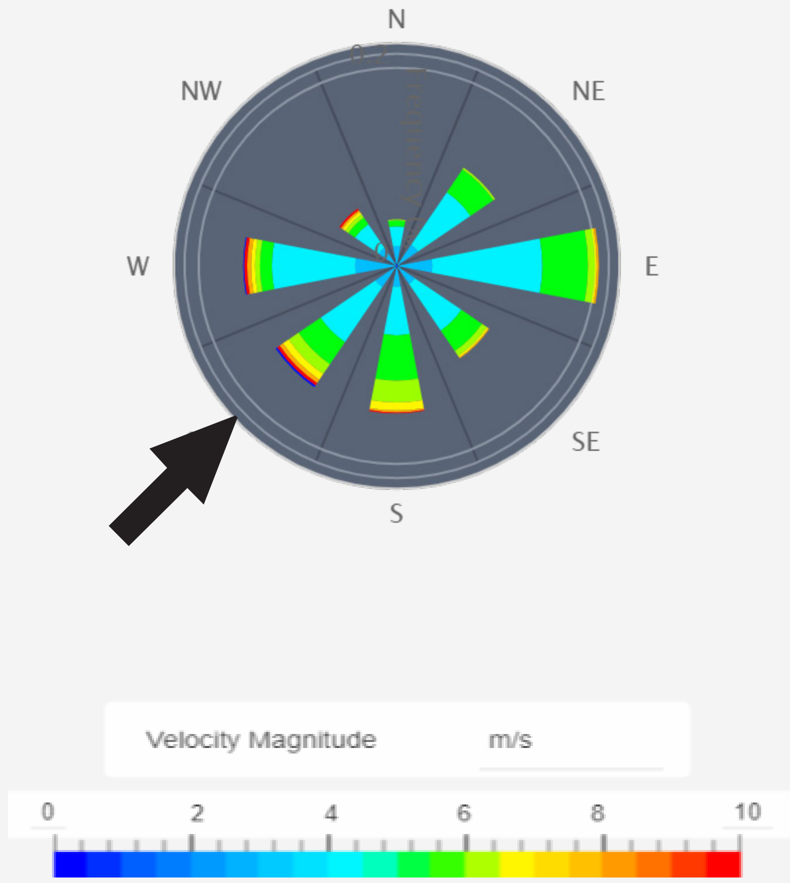
225°



Conclusion

The topography of the site, with a slope going from Southwest down to Northeast, combined with the native vegetation on the surrounding context causes the other two wind dominant wind directions: Southwest (225°) and West (270°) to have smaller impact in the comfort of the proposal.

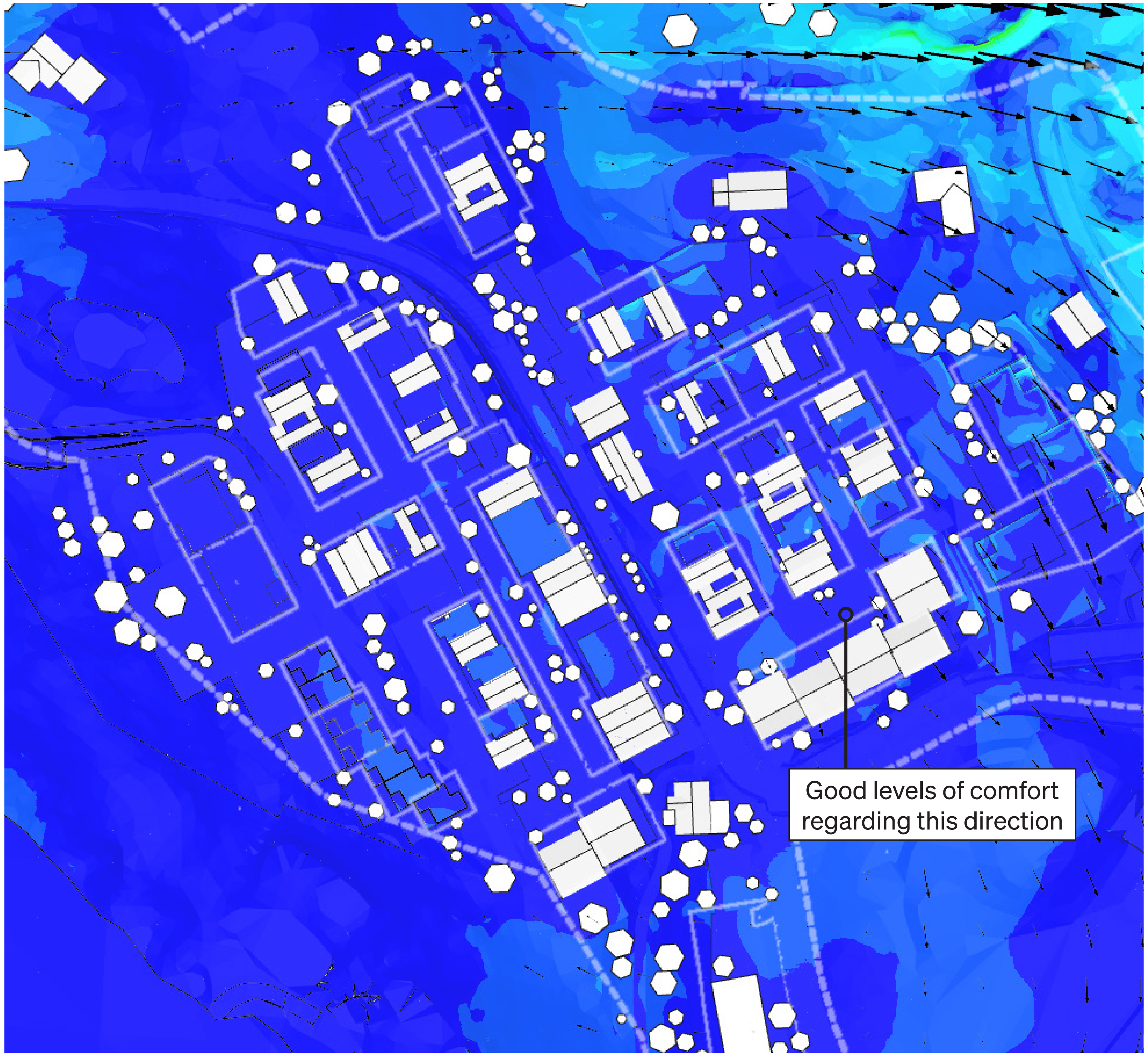
The ground level still performs relatively good in comfort levels regarding the Southwest (225°) wind, with very few places with a wind speed higher than 3.6m/s.



Predominant Winds Analysis: 270°

Wind conditions by each direction at Pedestrian level (1.5m) above the whole surface

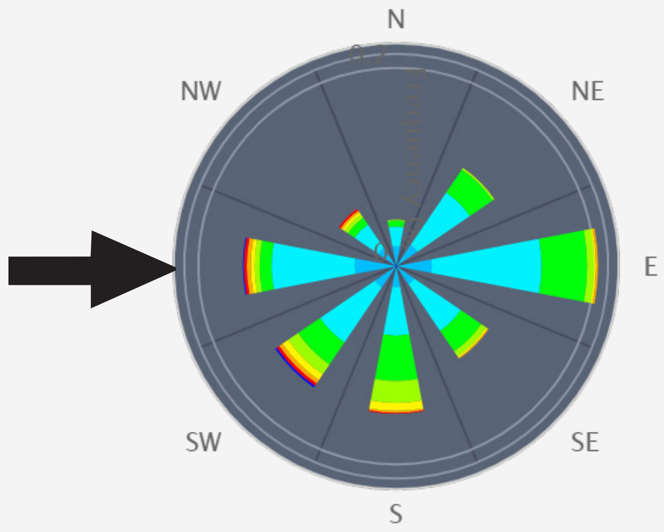
270°

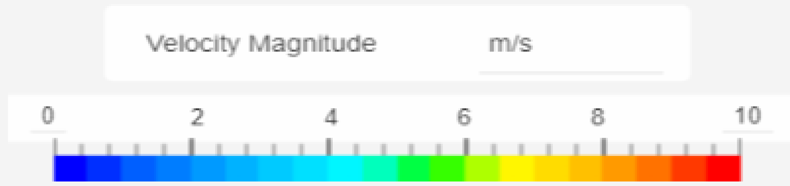


Conclusion

The topography of the site, with a slope going from Southwest down to Northeast, combined with the native vegetation on the surrounding context causes the other two wind dominant wind directions: Southwest (225°) and West (270°) to have smaller impact in the comfort of the proposal.

The ground level still performs relatively good in comfort levels regarding the West (270°) wind, with very few places with a wind speed higher than 2.5m/s.





Any questions?
Feel free to contact the LINK IO team!

Jan Buthke
jb@linkarkitektur.dk

Mathias Sønderskov Schaltz
mss@linkarkitektur.dk

Joel Lopez
jl@linkarkitektur.dk

Dolvik, Bergen

Wind Analysis Report

24.03.2022

LINK Arkitektur