VIND | VIND

WIND ANALYSIS

For:
The City of Tampere
December 2018
(rev. January 2020)
The Tampere Travel and Service Centre Masterplan, Finland

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Short introduction to wind analysis and Vind-Vind

In recent years, analyzes of wind comfort have come much more in the focus of municipalities, politicians, architects and builders due to urban planning and larger buildings - in the same way that sunlight and shadow diagrams have been standard for long.

Some the reasons are that more buildings are placed in wind-exposed areas, for example on shores, and that people in North Europe stays more outdoors, eg in cities and residential areas. In addition, IT-solutions have been developed in the form of so-called CFD programs. This makes it much easier to map wind and set up proposals for solutions and improvements early in the process of urban planning and / or construction.

Vind-Vind has since 2012 conducted analyzes for public authorities and other partners in urban planning and major construction projects in eg development areas in Scandinavia such as Nordhavn in Copenhagen, Thomas B. Thriges Gade in Odense, Lighthouse in Aarhus, Madla-Revheim in Stavanger and Citadell in Malmö.

Vind-Vind is founded by Per Jørgensen - educated physicist with many years of specialty in programming and computer simulations - and Leika Diana Jørgensen, MSc in Engineering and Bachelor of Commerce with experience from major engineering companies such as Rambøll, Sweco (before Carl Bro / Grontmij), Moe and Abeo.

Read more about wind comfort and about the company at www.vind-vind.dk

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1. INTRODUCTION

This report is prepared for the City of Tampere for the Tampere Travel and Service Centre (TTSC) masterplan. The aim of this report is to evaluate the future wind conditions of the urban areas in connection with the construction of TTSC. The wind conditions have been analyzed by using CFD calculations of the existing conditions and for future conditions. The calculations of future conditions are made both with and without trees. The wind environment has been evaluated in terrain, on the deck promenade and on the platforms of the station.

The wind comfort is characterized by the high buildings. The issue has been addressed in the planning and considered to reduce the intensity of wind in the living areas.

Large parts of the park have good wind comfort. In the southern part of the park there is an increased amount of wind, which is due to the high buildings - downwash. Also, in the north there will be downwash from High buildings. The challenge is met by planting several trees, in the area with downwash.

The cover of the arcade provides good shelter. On the deck promenade, there are several places where there is a lot of wind due to the high buildings. There will be pockets where the wind is less wind. It is obvious to place living areas in these pockets.

The train station does catch some the wind. In the southern part of the platform, it is recommended to establish some sheltering perpendicular on the train direction.

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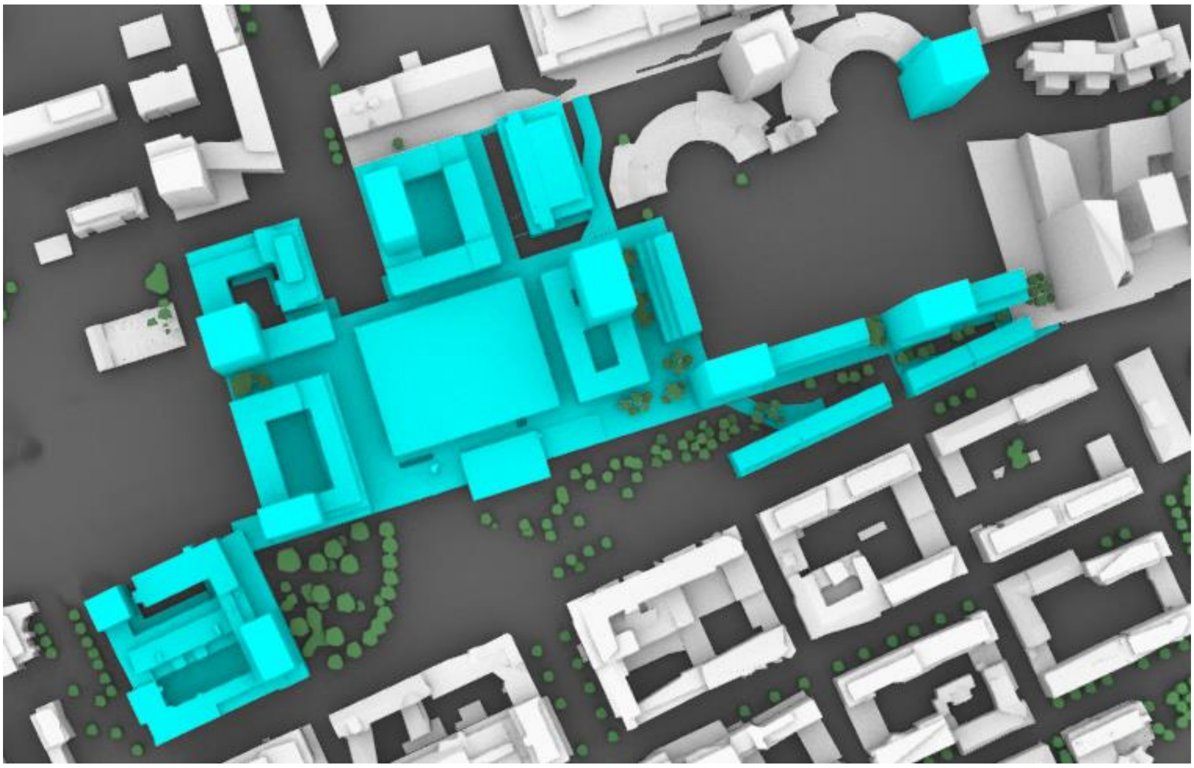


Figure 1: TTSC

2. IN GENERAL

The project is situated in Tampere in Finland. It is meant to connect the two parts of Tampere over the railway tracks. The new main station will be a central element in the project. The area will consist of some high-rise buildings next to a central park. In the east part of the surroundings there will also be some high-rise building. In western part there will exiting five- to seven-story buildings will be found.

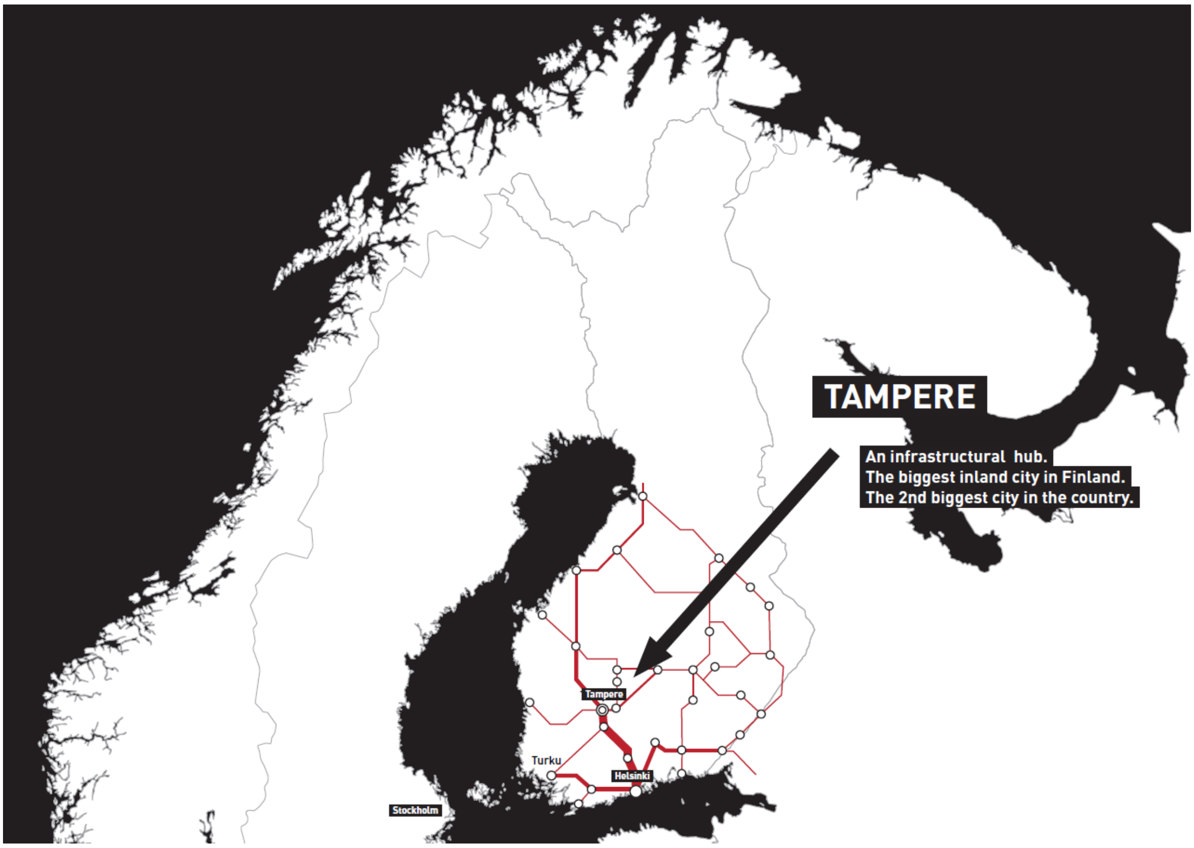


Figure 2 Tampere

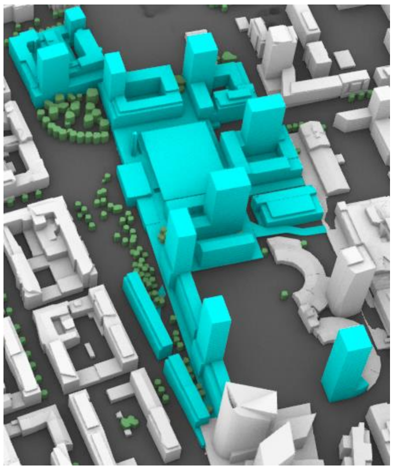


Figure 3 Overview of the area

3. PRESUMPTIONS AND METHOD

CFD calculations have been used to evaluate the future conditions. Wind is a very complex phenomenon, and it can be difficult to identify exactly where the problems arise. The CFD calculations relate to the individual influences and their interactions.

3.1 Basis of Calculations

The CFD-program OpenFOAM[1] has been used. Wind speeds are examined in the areas around the buildings at a height of 1.50 m above the surveyed area, typically terrain - corresponding to an average pedestrian head height. The comfort overviews follow the terrain. Considering that wind direction and wind speed vary over time, it can be statistically predicted how often a critical wind speed will occur in a given area. Wind conditions vary over the year - from month to month. The report assesses wind comfort in relation to the annual average. As seen from the wind roses in Appendix 1, the southwest wind is dominant in Tampere.

3.2 Comfort Criteria

Wind comfort is very individual and specific to the use of area. Good wind comfort depends indeed-on people's expectations. Generally, people are more tolerant of wind when they are eg. close to the ocean. The temperature can also influence the experience of the wind. The pictures below show two very different wind situations. At the coast of the North Sea it can be an attraction that it is extremely windy. While at a café in Tampere or in Helsinki you most likely would not tolerate much wind.


Figure 4 Experience of wind. The North Sea with about 20 m/s and Tampere with 0-2 m/s

The results of the calculations will be evaluated in relation to the so-called Davenport comfort table. The table below shows the different categories in relation to how much of the time the comfort criterion of 6 m/s has been exceeded in percentage. For example, if the wind speed is more than 6 m / s for 6% of the time, an average person will feel comfortable for stays in shorter periods of time,
but not so comfortable for longer stays.

Activities	Area	Characteristics of the wind environment		
		Acceptable	Unpleasant	Very unpleasant/unsafe
Walking fast	Pavement and paths	43%	50%	53%
Strolling	Parks and shopping streets	23%	34%	53%
Standing and sitting for short period	Parks and squares	6%	15%	53%
Standing and sitting for longer periods	Outdoor restaurant	0,1%	3%	53%

Tabel 1 A. Davenports comfort table

The report provides an overall evaluation of specific areas in the park, on the deck promenade and the platform of the station. The primary focus is on the overall wind speed. However, air drop / downwash can be a factor that can also impair the experience of comfort.

If there is gust of more than 20 m/s locally, weak walking will have difficulty keeping the balance. Therefore, this safety criterion will also be examined.

[1] Open Field Operation and Manipulation

3.3 Calculation Area

The calculations used an area of 1.2x1.7 km, of which approximately 400 X 650 m modeled fine, where future construction is modeled with high level of detail and the nearby existing area with a lower level of detail, see Figure 5. The roughly modeled area ensures that the wind develops according to local conditions. The roughly modeled area will only appear as roughness in the calculations. Wind conditions in the rough area will therefore not be correct, especially not near buildings. It is only within the finely modeled area that the results are accurate.

The modeling is based on 3D models of the future construction, handed out by Cobe.

Figure 5. shows a digitized ground plan of the area around TTSC.

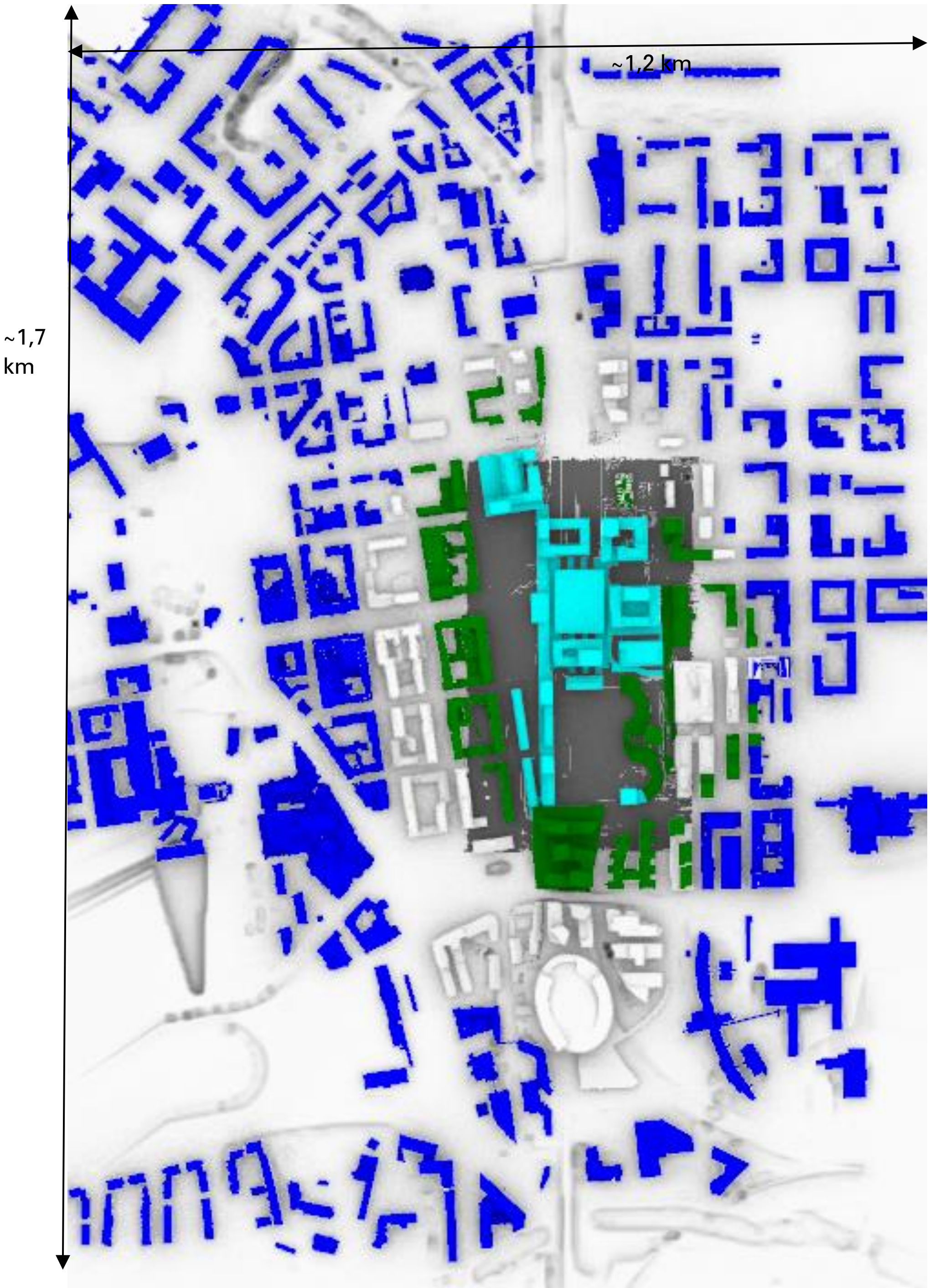


Figure 5 Buildings in the calculated area around TTSC.

The model will be calculated for wind 12 different wind directions: 0°, 30°, 60°, 90°, 120°, 150°, 180°, 210°, 240°, 270°, 300° og 330°.

4. WIND COMFORT IN THE FUTURE PLAN

Wind comfort for the future conditions, respectively, with and without trees, see Figure 6 and Figure 7. Sub-areas are described in the following sections.

Large parts of the park have good wind comfort. In the southern part of the park there is an increased amount of wind, which is due to the high buildings - downwash. Also, in the north there will be down-wash from High buildings. The challenge is met by planting several trees, in the area with downwash.

The cover of the arcade provides good shelter. On the deck promenade, there are several places where there is a lot of wind due to the high buildings. There will be pockets where the wind is less strong. It is obvious to place living areas and cafes in these pockets.

The train station does catch some the wind. In the southern part of the platform, it is recommended to establish some sheltering perpendicular on the train direction.

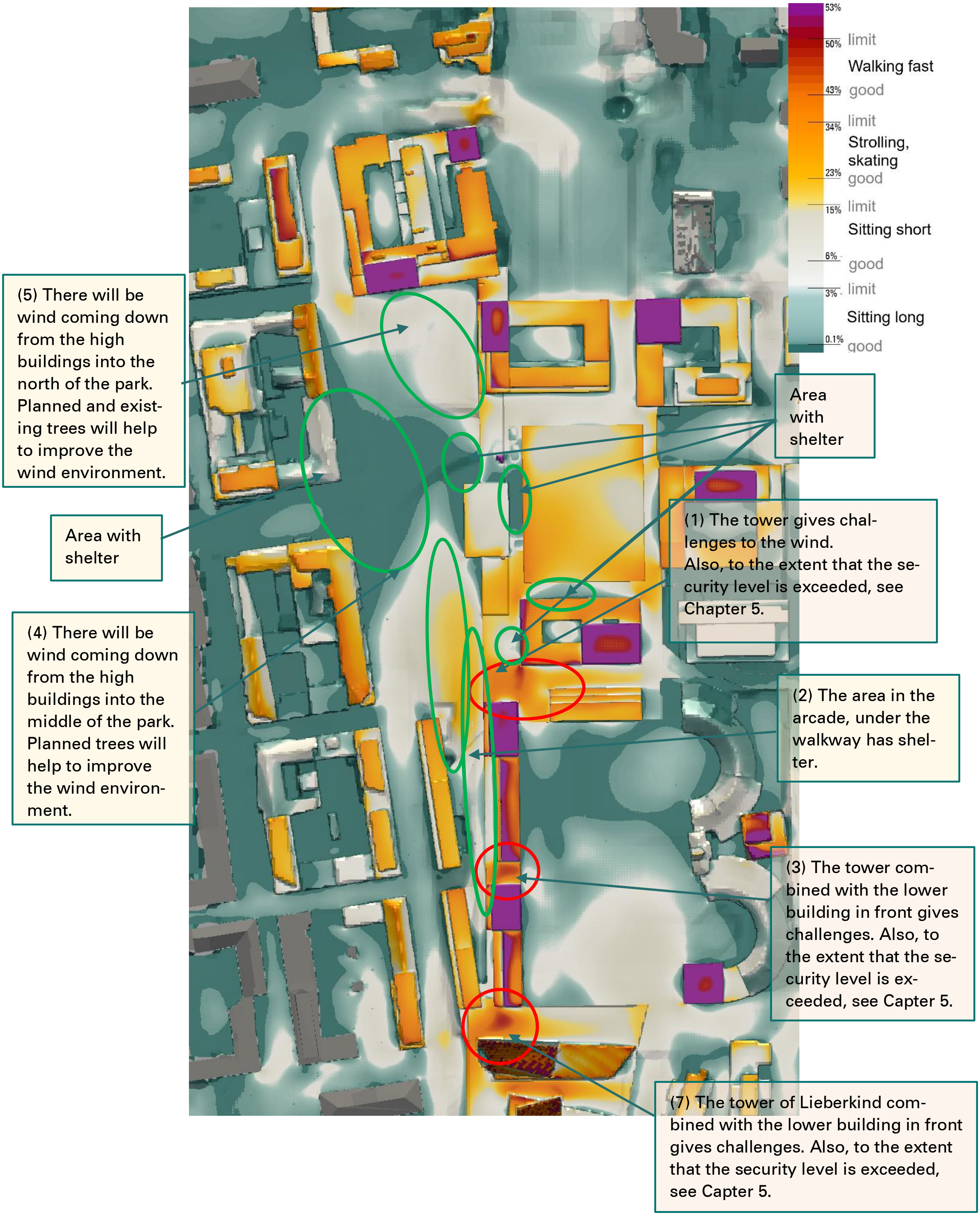


Figure 6 Calculations of future conditions without planting. Total comfort criterion exceeded. Percentage period where comfort requirements of 6 m/s are exceeded in one point.

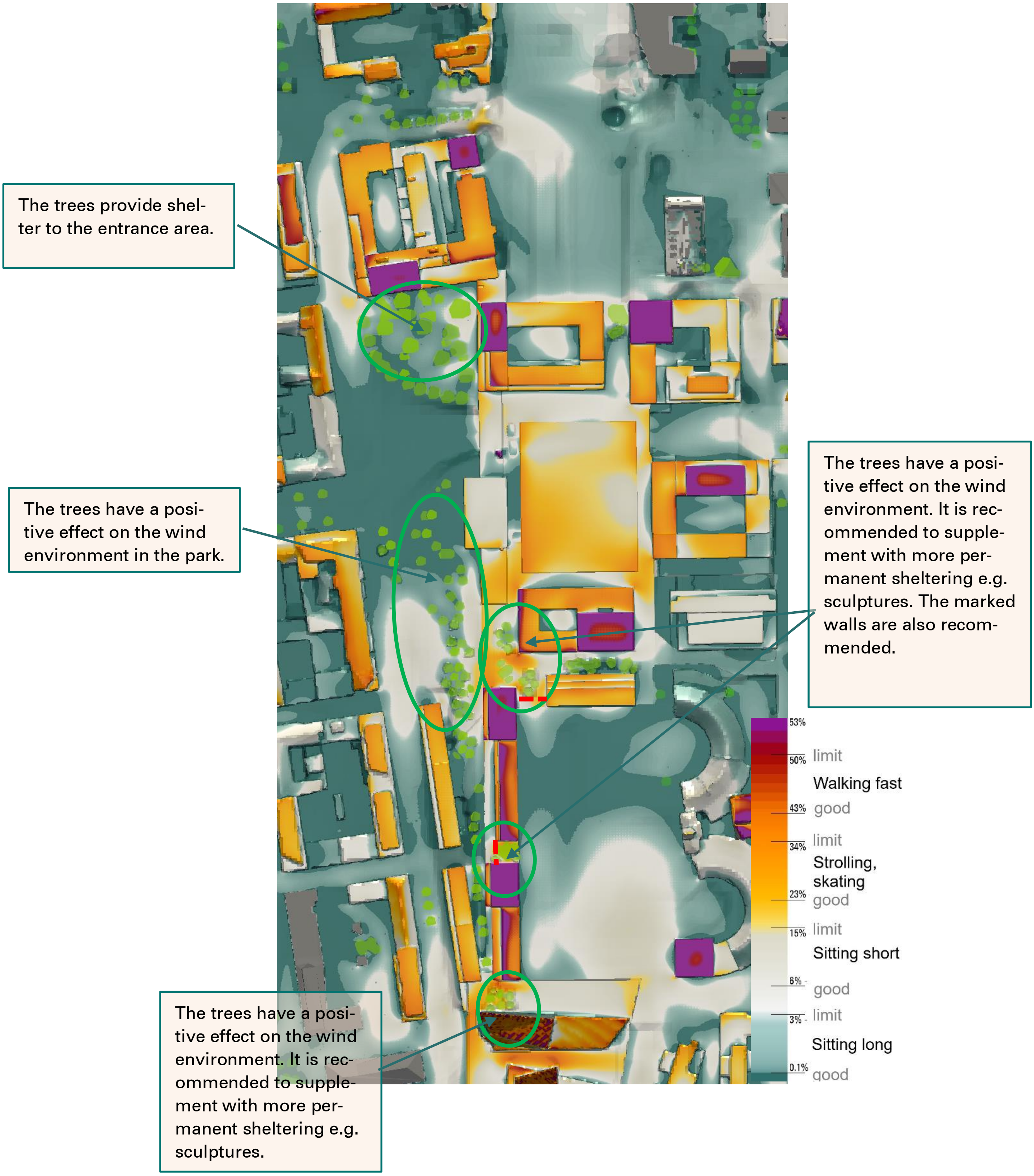


Figure 7 Calculations of future conditions with planting. Total comfort criterion exceeded. Percentage period where comfort requirements of 6 m/s are exceeded in one point.

4.1 Middle Tower

The streamlines due to the area near the tower in the middle is shown in Figure 8. The area is dominated by the wind from the high-rise building. However, the area is also influenced by the wind caught in a sort of funnel formed by the surrounding buildings.

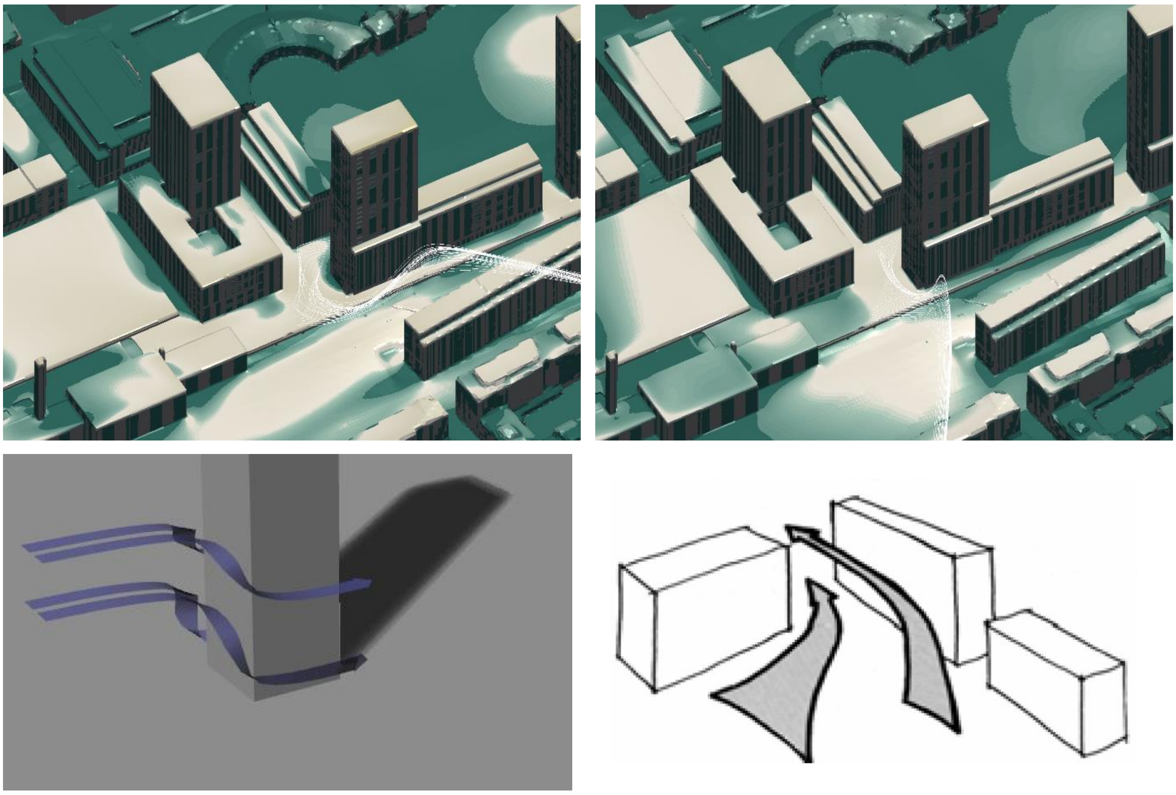


Figure 8 Streamlines that shows how the wind gets to the Middle Tower due to wind from West-southwest and West-northwest.

The wind will be very strong at base of the high-rise building. The trees will reduce some of the wind. However, even with trees the area will be windy. The trees must also be resident to wind to be able to grow. It is recommended that the trees are supplemented with some sheltering constructions. That could be a kind of sculpture. It is also recommended to place a wall in between the buildings south from the area, see Figure 7.

4.2 The Arcade

The wind comfort in the arcade is shown in Figure 9. It shows the wind comfort in the arcade and how the walkway will provide shelter.

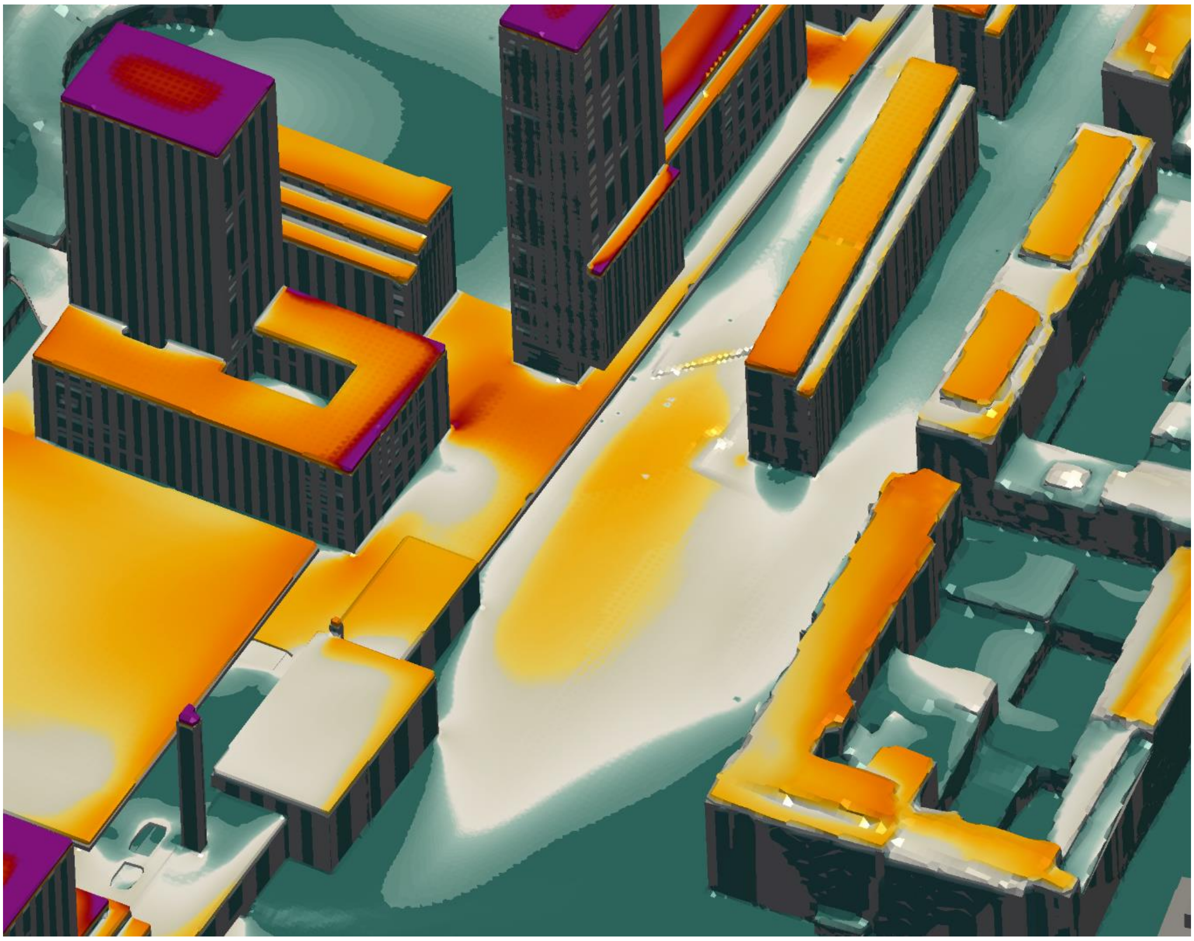
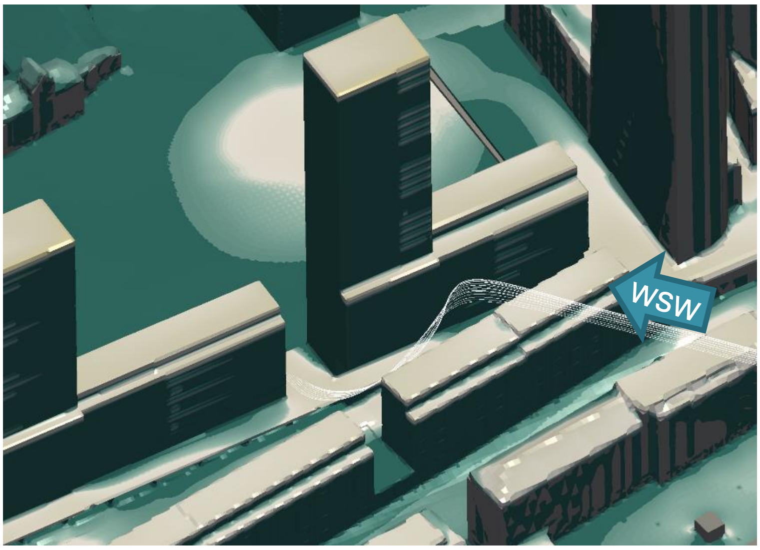


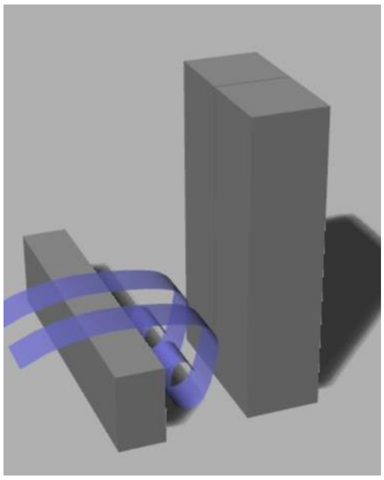
Figure 9 Calculations of future conditions without planting in the arcade. Total comfort criterion exceeded. Percentage period where comfort requirements of 6 m/s are exceeded in one point.

4.3 The Tower in South

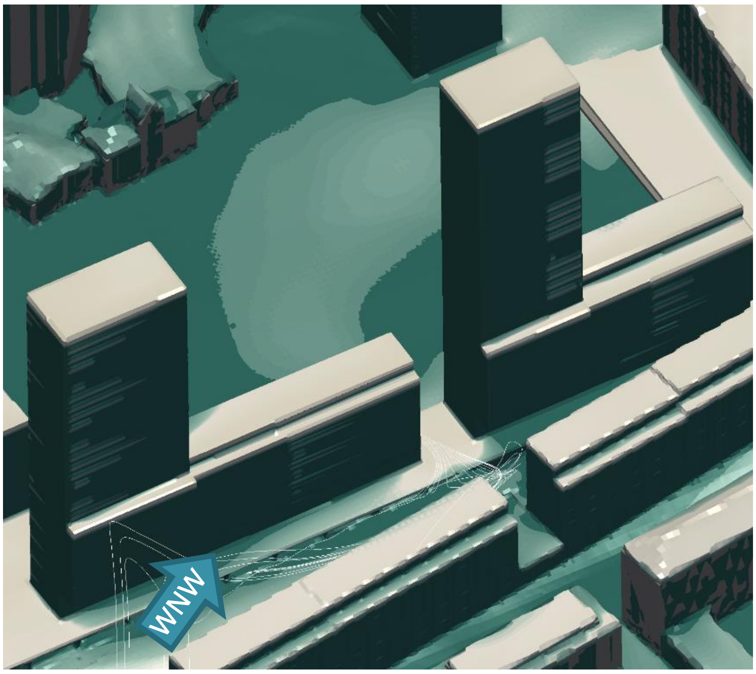
The streamlines due to the tower in the northern area/part is shown in Figure 10. Below. The wind coming from WSW is forced over a relatively low building, and afterward caught by the high-rise building. Turbulence between the two buildings will appear.

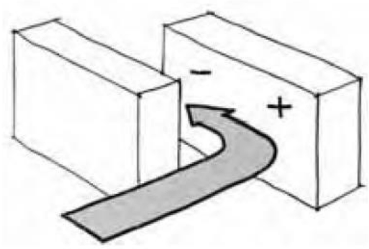
Wind from WNW will slide along the façade. However, the gap in the façade line will bend the wind off due to the pressure differences~~.~~





Wind from WSW





WNW

Figure 10. Streamlines show-how the wind gets to the tower in South due to wind from West-southwest and West-northwest.

The wind will be very strong at base of the buildings. The trees will reduce some of the wind. However, even with trees the area will be windy. The trees must also be resident to wind to be able to grow. It is recommended to place a wall in between the buildings.

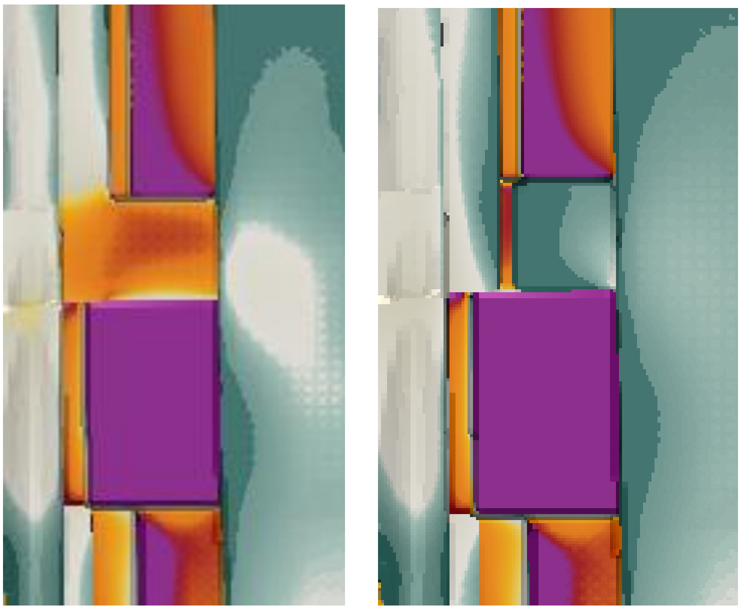
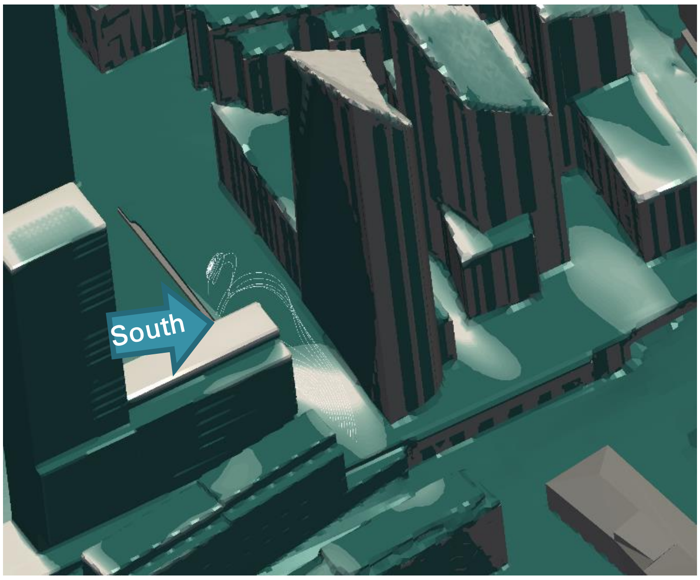
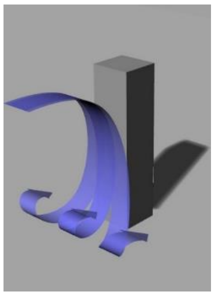


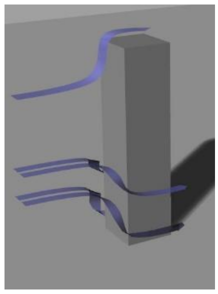
Figure 11. The effect of having a wall between the buildings. Left: without a wall, right: with a 5-meter-high wall.

4.4 The towers of Lieberkind

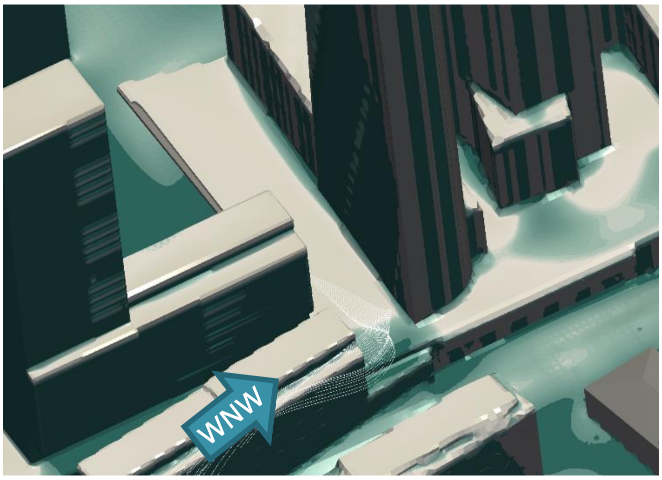
The streamlines due to the tower of Lieberkind in the south area/part is shown in the figure below. The wind from south and western directions gets caught by the high-rise building

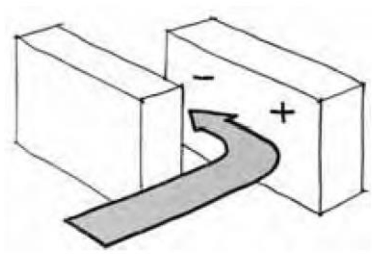






Wind from WSW





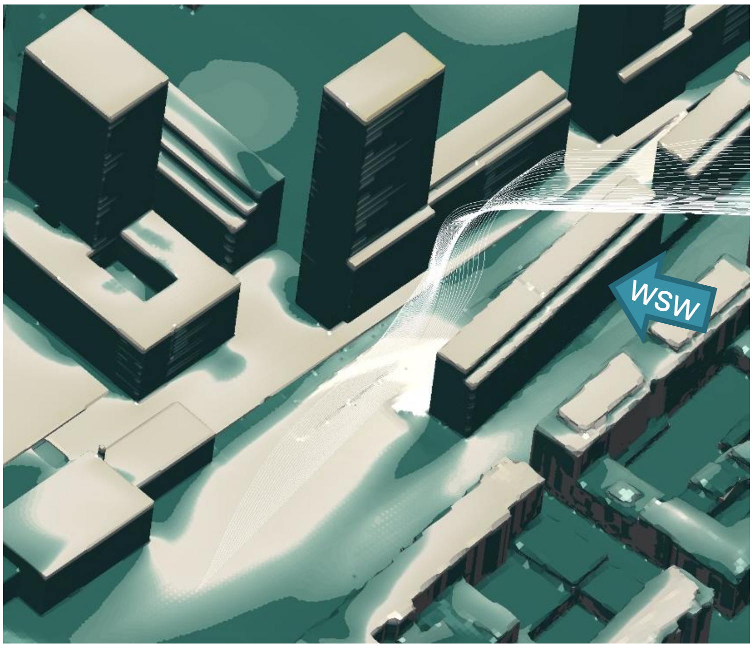
WNW

Figure 12. Streamlines show-how the wind gets to the Lieberkind-tower due to wind from South and West-northwest.

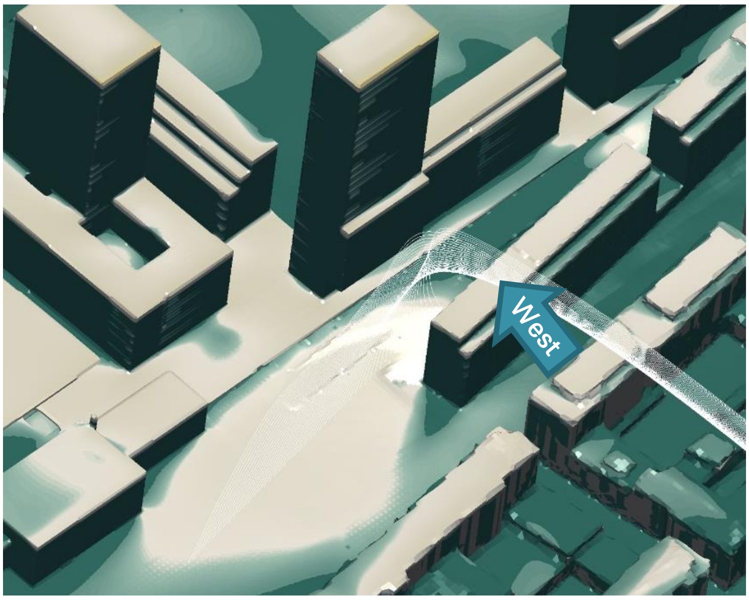
The wind will be very strong at base of the buildings. The trees will reduce some of the wind. However, even with trees the area will be windy. The trees must also be resident to wind to be able to grow. It is recommended to place permanent structures to reduce the wind in between the buildings. It could e.g. be sculptures.

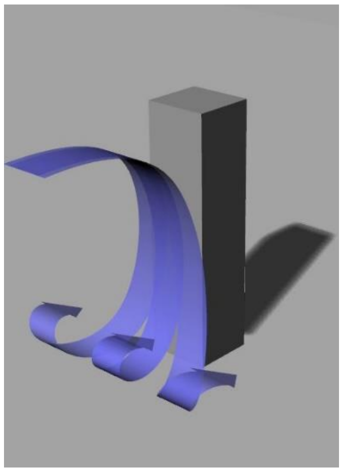
4.5 The Park

The wind comfort in the park is dominated by downwash from the high buildings, especially from the tower in the middle. Figure 13 shows the streamlines, when the wind is coming from WSW and West. The planned-trees are placed to accommodate the downwash.



Wind from WSW



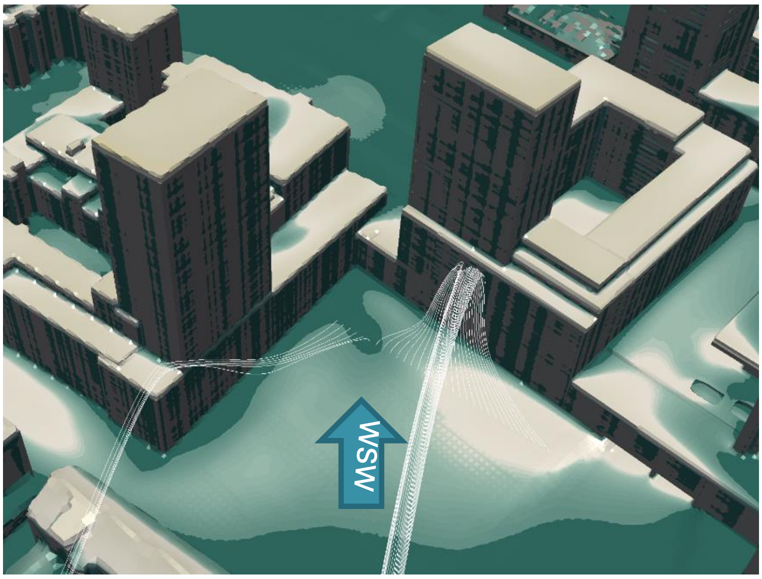


West

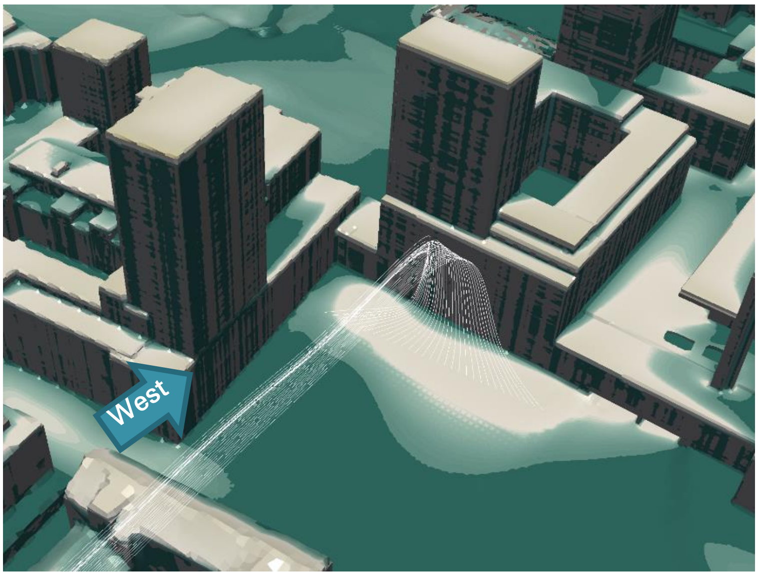
Figure 13. Streamlines show how the wind gets to the park due to wind from West-southwest and West.

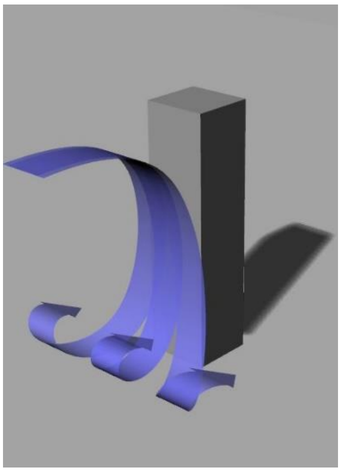
4.6 The North part of the park

The wind comfort in front of the tower in North is dominated by downwash from the high building. Figure 14 shows the streamlines, when the wind is coming from SSW and WSW. The large base East of the tower prevents more wind to downwash.



Wind from WSW





West

Figure 14. Streamlines show how the wind gets to the tower in North due to wind from West-southwest and West.

4.7 The station

As seen in Figure 15, the comfort of the platform is acceptable. However, it is recommended that on the middle and eastern platform local shelter for waiting passengers will be established in the southern part. At the upper level, there is more wind. There will be areas where the wind comfort corresponds to that it will be comfortable to stay for shorter time. At the corners of the neighbour building there will be extra windy.

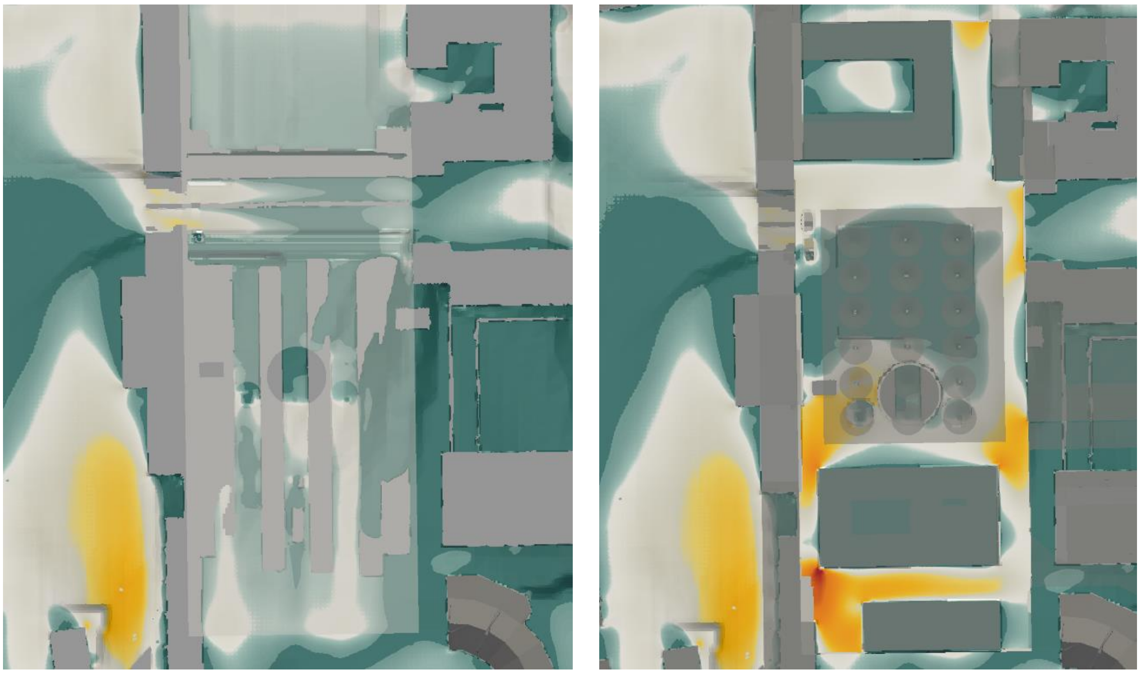
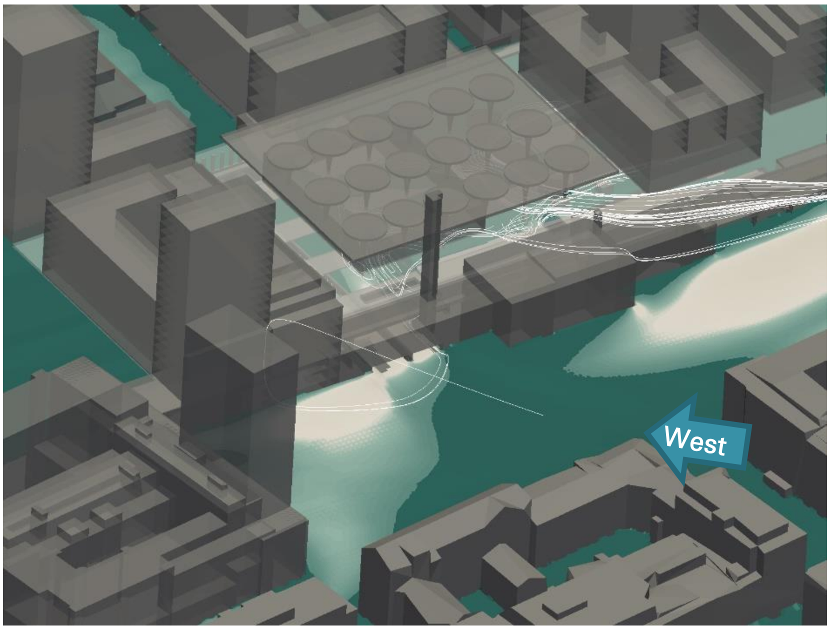
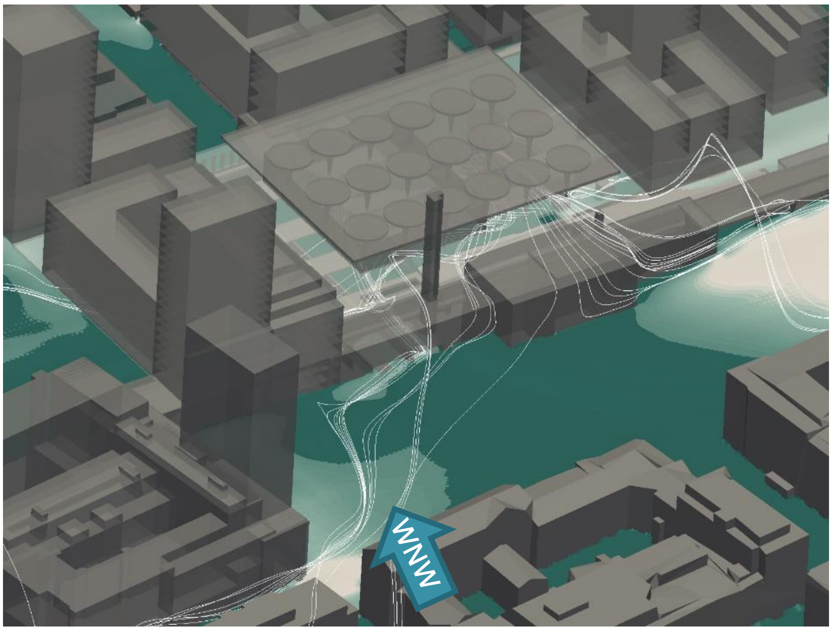


Figure 15. Calculations of future conditions without planting at the station, the lower level and the upper level. Total comfort criterion exceeded. Percentage period where comfort requirements of 6 m/s are exceeded in one point.

From Figure 16, shows how the wind gets down to the platforms. For some direction the wind will be caught in the southern part of the east and middle platform. The wind will follow the train direction. Sheltering perpendicular on the train direction will be efficient.



Wind from west



West-northwest

Figure 16. Streamlines show how the wind gets to the tower in North due to wind from West-northwest and West.

5. ANALYSIS OF THE SAFETY LEVEL

Figure 17 below is an overview showing whether the safety level is exceeded in future conditions.

If the local wind speed more than 20 m/s, weakly people will have difficulty keeping the balance. Over-run can better be accepted in areas where there are no pedestrian crossings

There will be areas in the park where there will be strong winds. However, we do not see this as a prob-lem as people will be able to have shelter in the arcade.

On the deck promenade there are several places where the safety level is exceeded - especially at the high buildings. When the wind is strong, people can choose to go along the arcade under the deck promenade

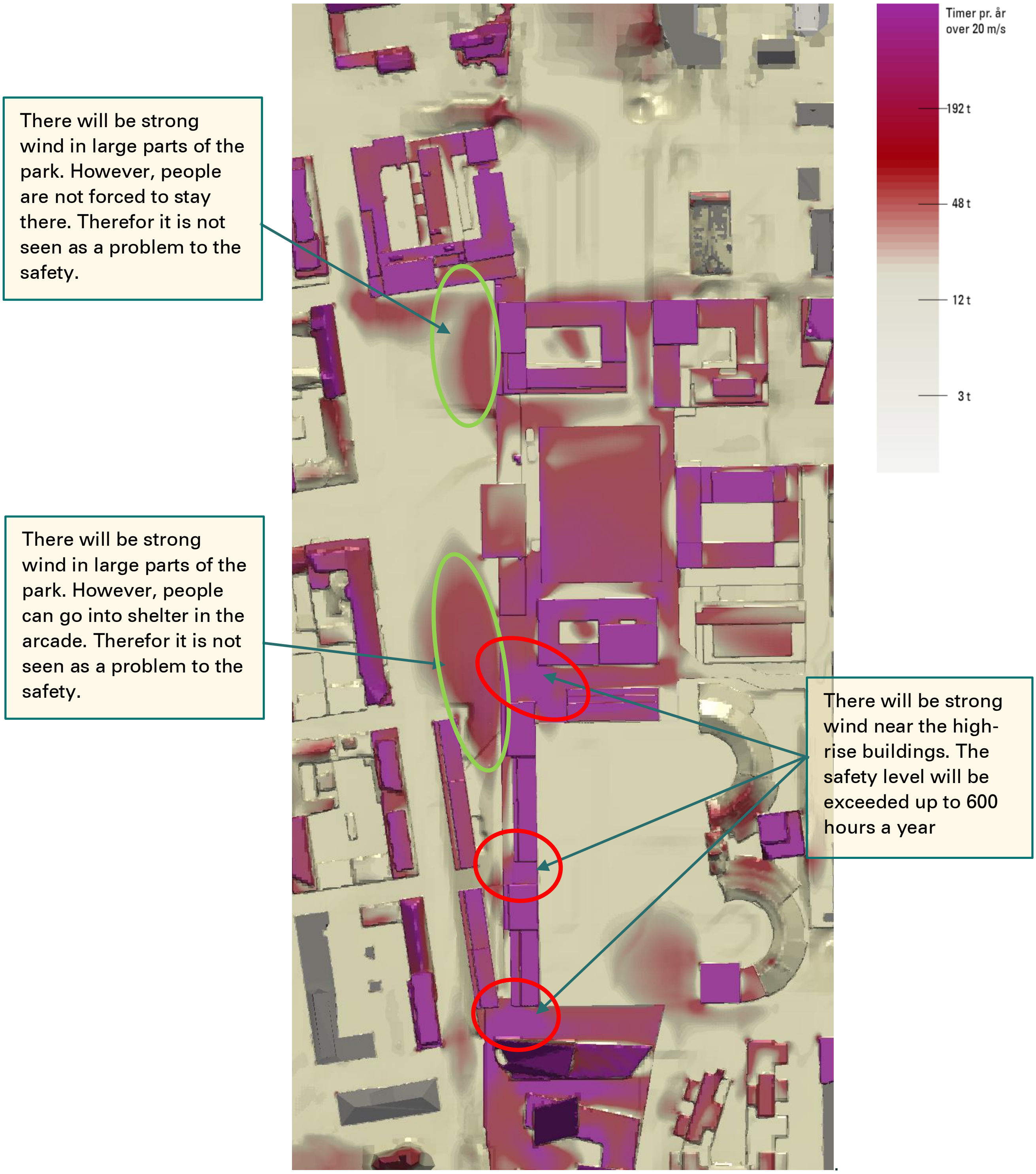


Figure 17. Overview of the safety level in the future plan (without trees)

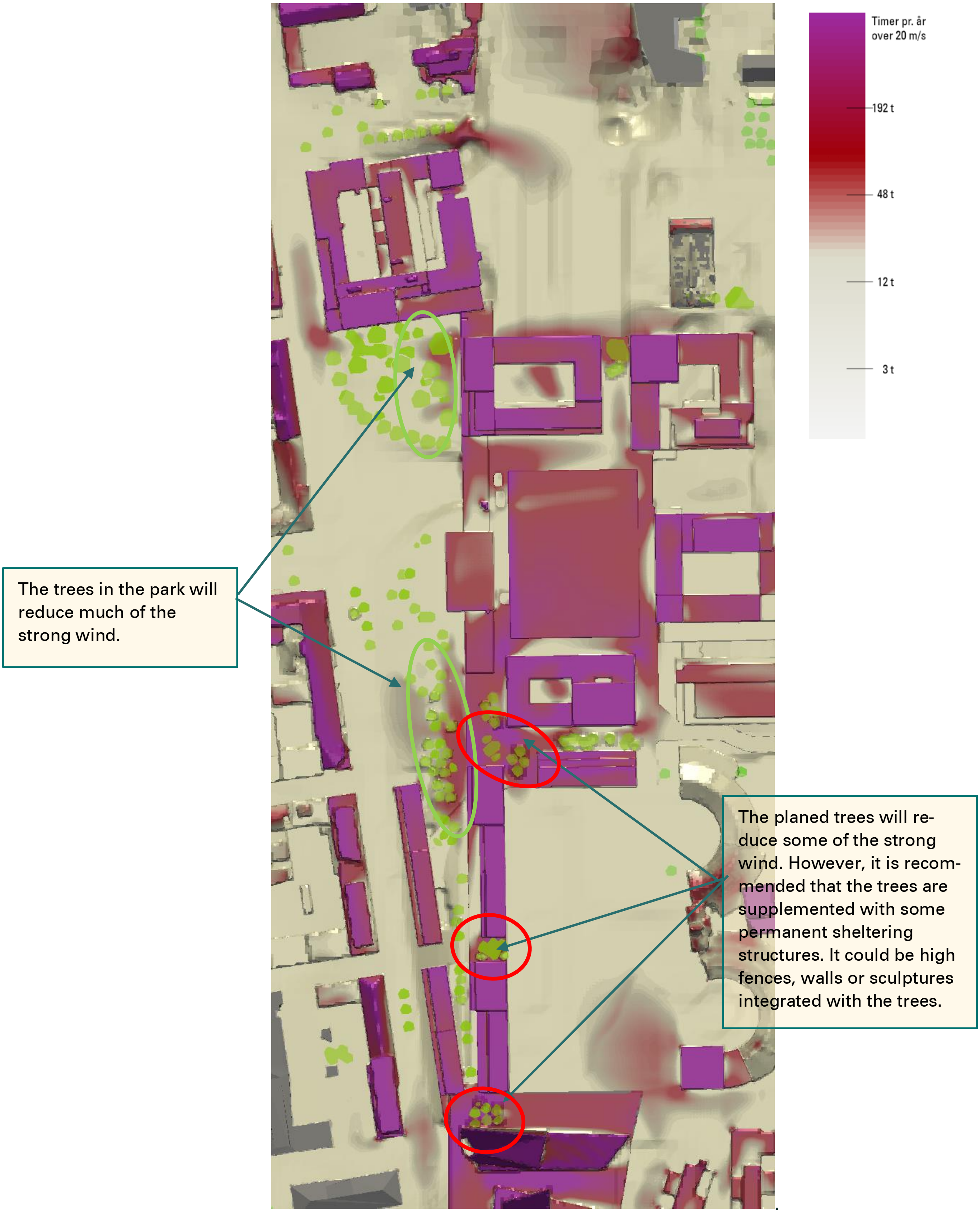


Figure 18. Overview of the safety level in the future plan (with trees)

6. REFERENCES

Bottema, M., A method for optimisation of wind discomfort criteria, Building and Enviroment, 35, 2000

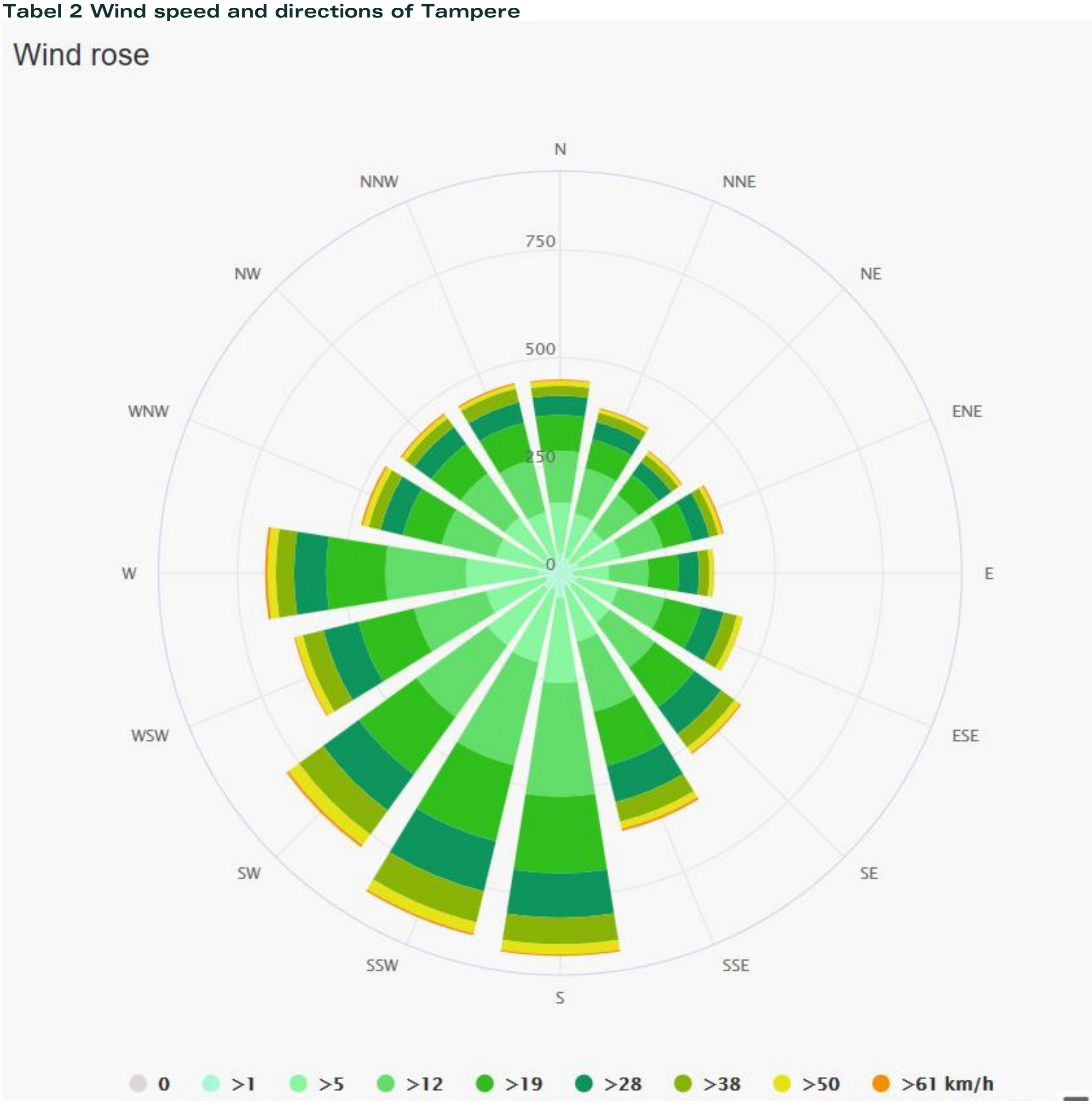
SBI-ansvisning 128, Vindmiljø omkring bygninger, Statens Byggeforskningsinstitut

Wellington City District Plan, Design Guide for Wind, 2000-07-27

APPENDIX 1 – WIND STATISTIK

Wind data from Tampere has been used. The results of the observations can be seen in Tabel 2

Tabel 2 Wind speed and directions of Tampere



The indicated wind speeds are "10 minutes mean wind speed" observed at 10 meters height. Wind speeds and wind directions vary throughout the year. In the report, the annual average is used.

Input-data

The boundary conditions for the numerical calculation are the undisturbed flow. The flow profile is given by:

$$U = \frac{U_*}{\kappa} ln\left(\frac{z}{z_0}\right)$$

Where U [m/s] is the friction velocity, κ [-] is von Karman number, z [m] is the hight, and z_0 [m] is the roughness length. z_0 is specified to 0.5 m. equivalent to city area.

The roughness length on the surface has been investigated for 0.2 m and 0.02 m. The roughness length has no significant influence on the results.

Criteria of Comfort and Safety

Comfort and safety are very subjective feelings, therefore any attempt to set criteria will be associated with some uncertainty. As a starting point, the results will be assessed in relation to a comfort and safety criterion that has been set up by Bottema, A., "Method for optimization of wind discomfort criteria", Building and Environment, 35, 2000.

Comfort: $U + \sigma_u > 6m/s$

Safety: $U + 3\sigma_u > 20m/s$

Where σ_u is the spread of speed (turbulence). Turbulent kinetic energy, k, is used to determine the turbulence of the turbulence, which is the local turbulence. The global turbulence is incorporated into the incoming wind profile.

Turbulence: $k = ½\overline{u_i' u_i'} \rightarrow \sigma_u = 2\sqrt{k}$

Where u_i' is the fluctuating part of the flow rate.

The comfort criterion relates to sedentary activities. In other literature, such as the Wellington City District Plan, it is estimated that people can accept up to 10 m / s if they must stand up for long time at a time, and 15 m/s when they walk. The fact that the comfort criteria are met is not the same as it is windless.

The excess frequency is assessed in instructions in SBI 128, originally prepared by A. Davenport, see Tabel 3. SBI 128 / Davenport uses a criterion of 5 m/s. This wind speed is an actual wind speed. Bottemas, on the other hand, have incorporated the turbulence and increased the comfort criterion to 6 m/s. Variations in wind (turbulence) give less comfort than even wind. The two criteria are comparable.

We believe that it will be more accurate to use Bottema's criterion where the turbulence is incorporated. We use Davenport's excess percentage, however, as it gives a more nuanced picture of different comfort areas.

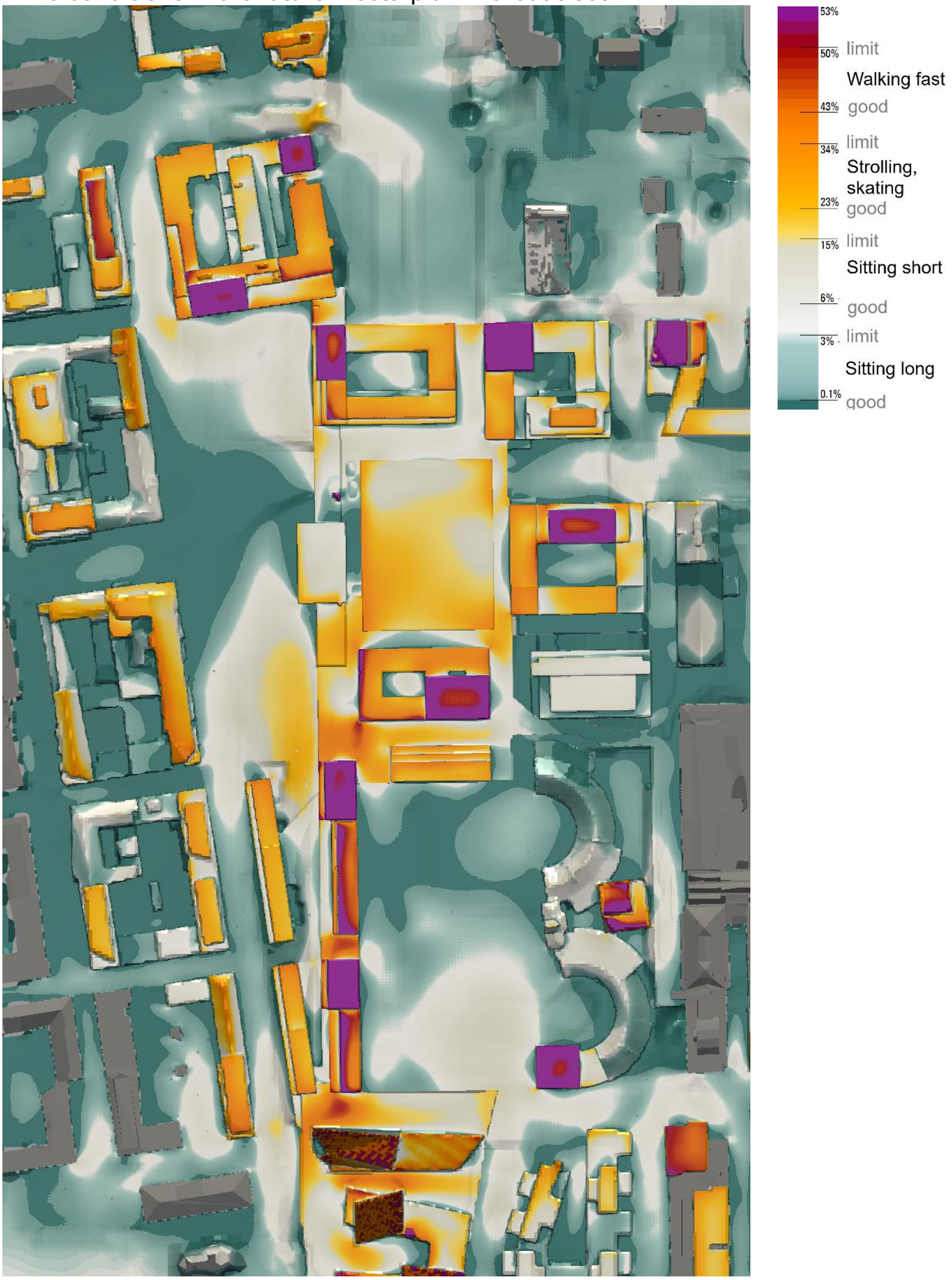
Activities	Area	Characteristics of the wind environment		
		Acceptable	Unpleasant	Very unpleasant/unsafe
Walking fast	Pavement and paths	43%	50%	53%
Strolling	Parks and shopping streets	23%	34%	53%
Standing and sitting for short period	Parks and squares	6%	15%	53%
Standing and sitting for long periode	Outdoor restaurant	0,1%	3%	53%

Tabel 3 A.Davenports comfort tabel

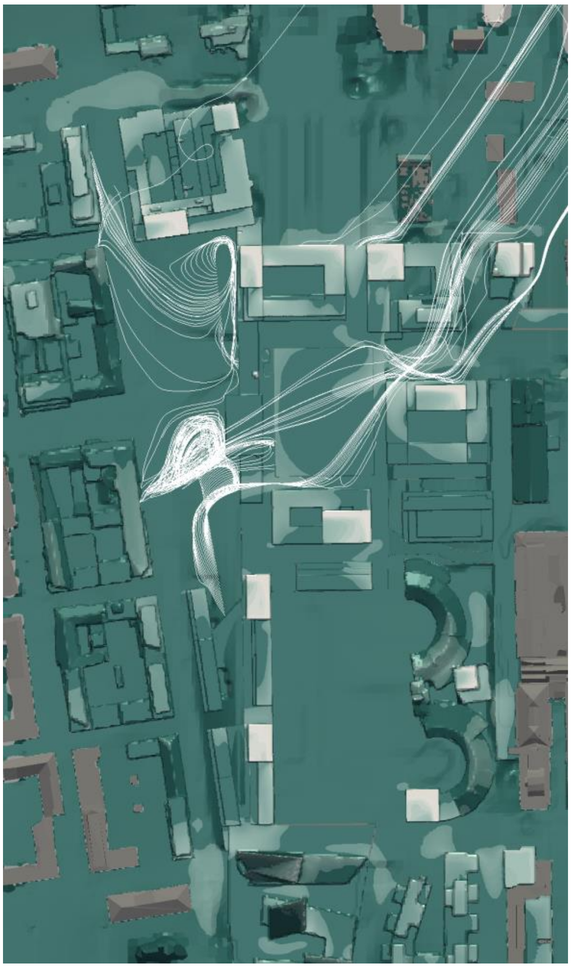
An area may well be comfortable even if the comfort criterion has been exceeded in periods. For example, it may be in areas located near the sea where it is expected to be windy. Each area must be evaluated individually in terms of how long the comfort and safety criteria can be exceeded and when this is acceptable.

APPENDIX 2 – OVERVIEW MAP

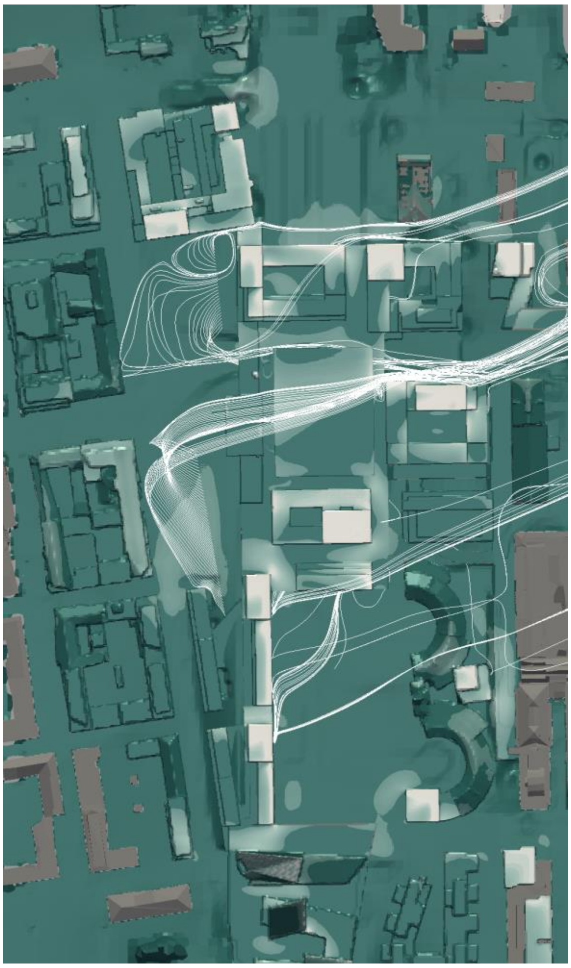
Wind conditions in the future masterplan without trees.



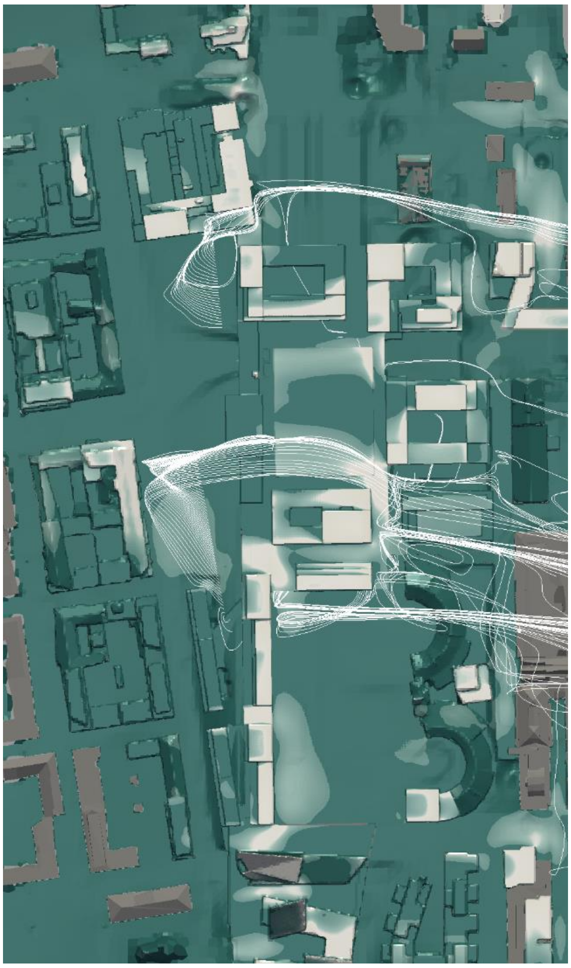
Total



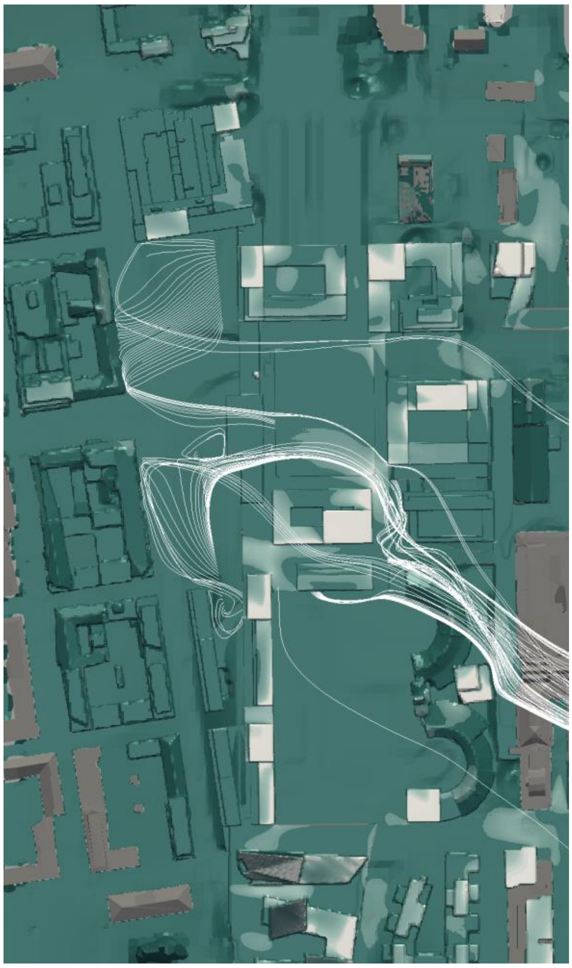
30°



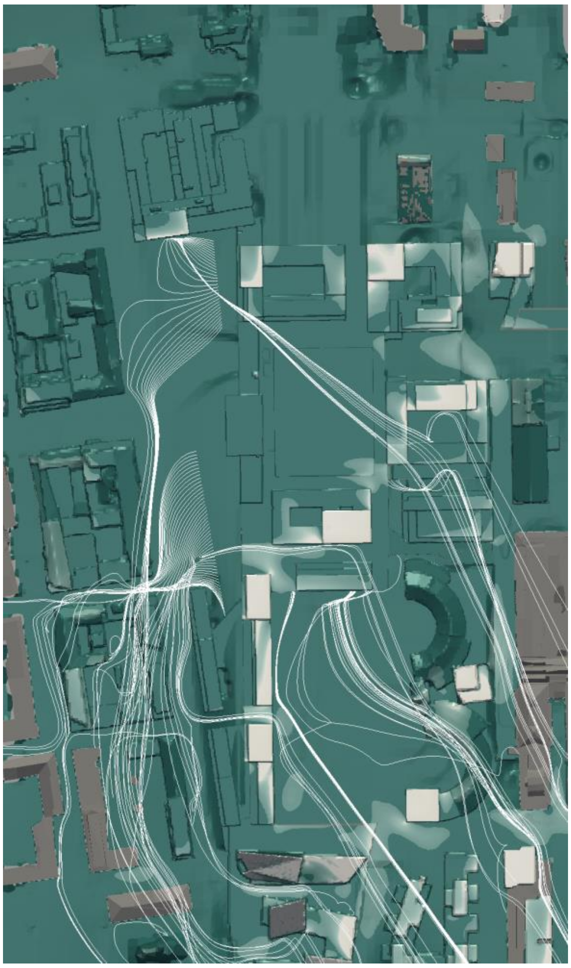
60°



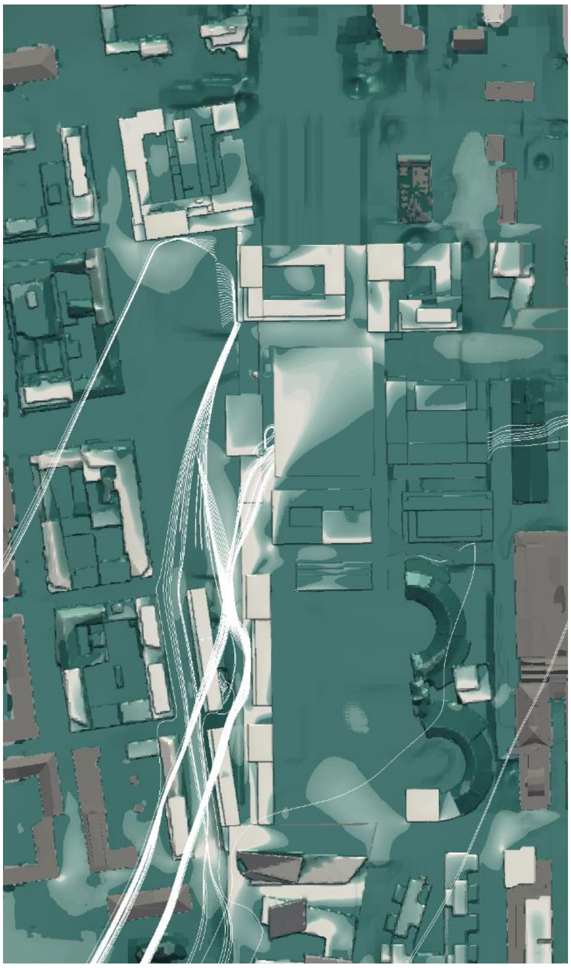
90° (East)



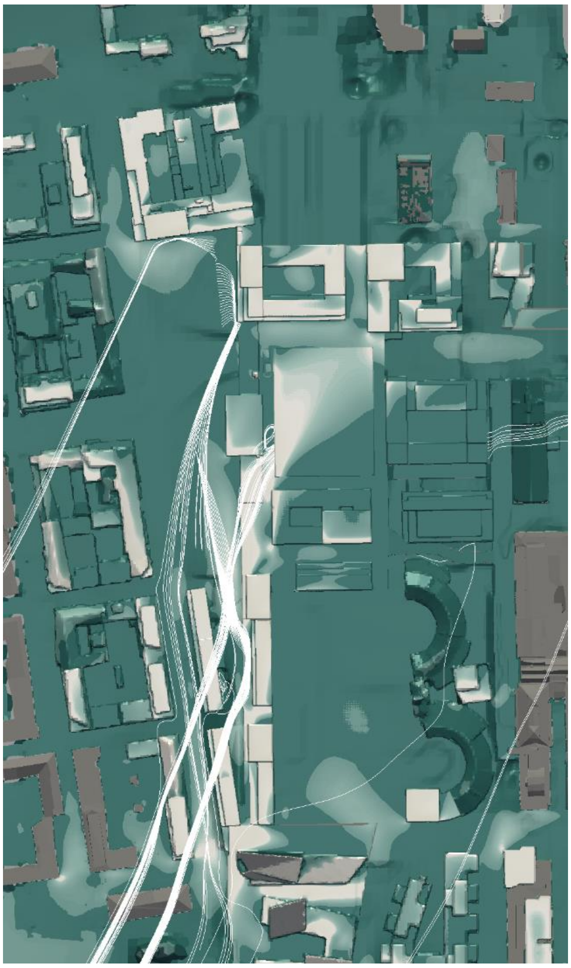
120°



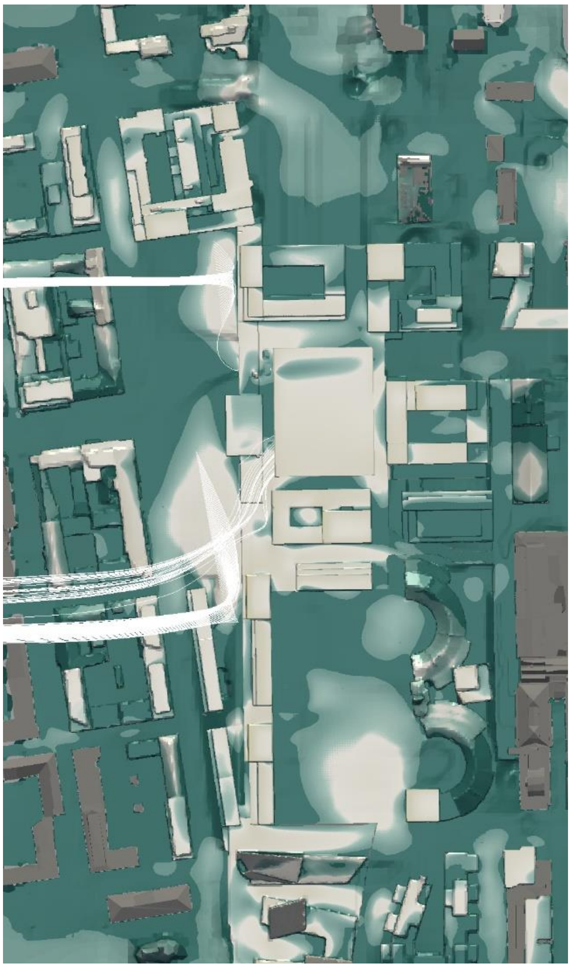
150°



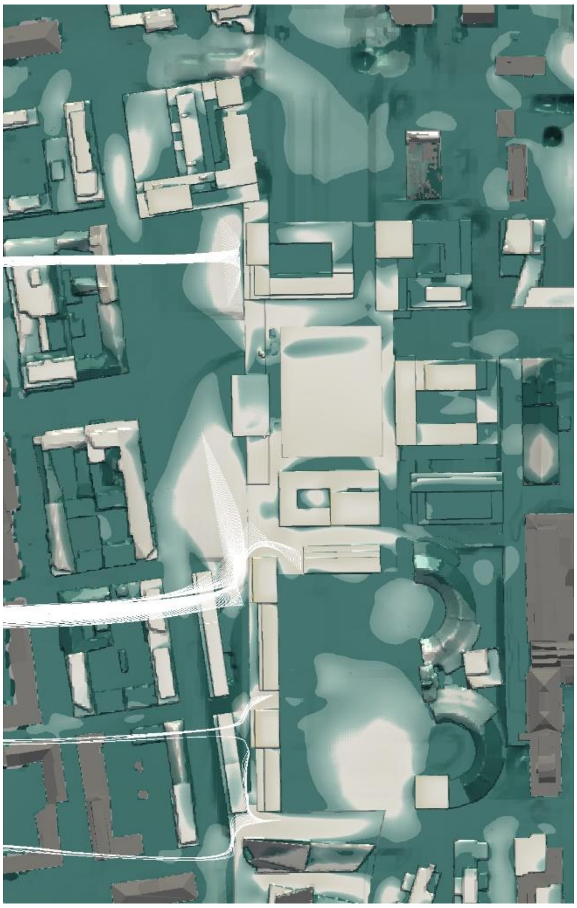
180° (South)



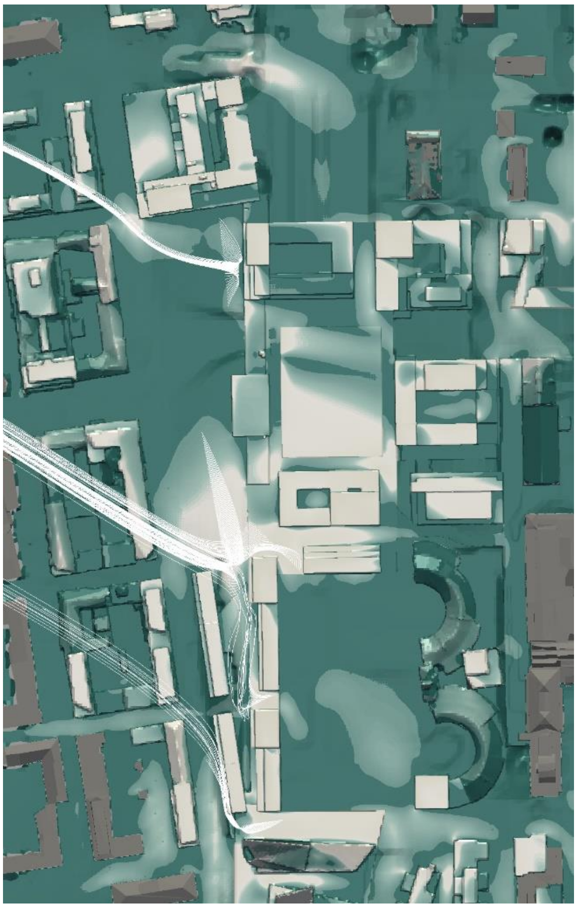
210°



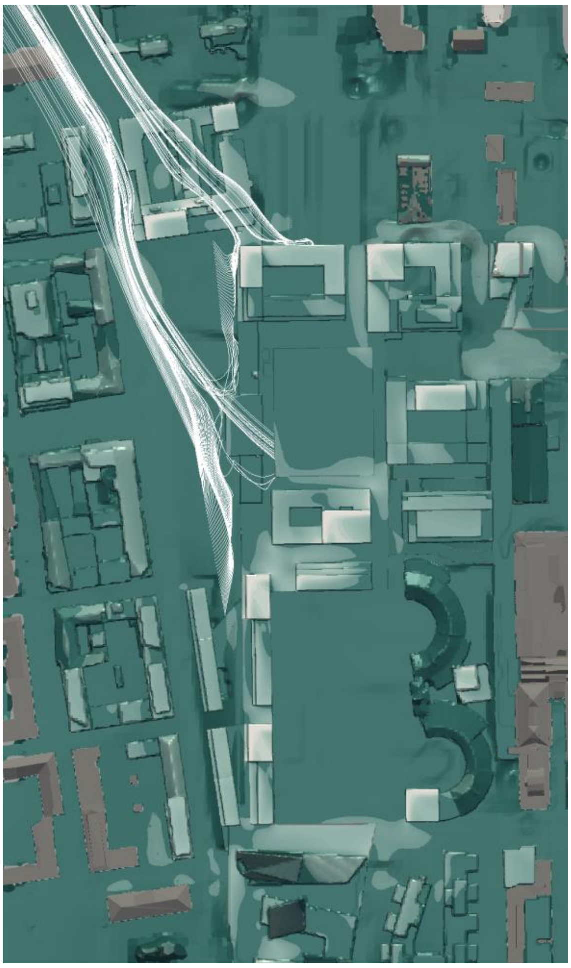
240°

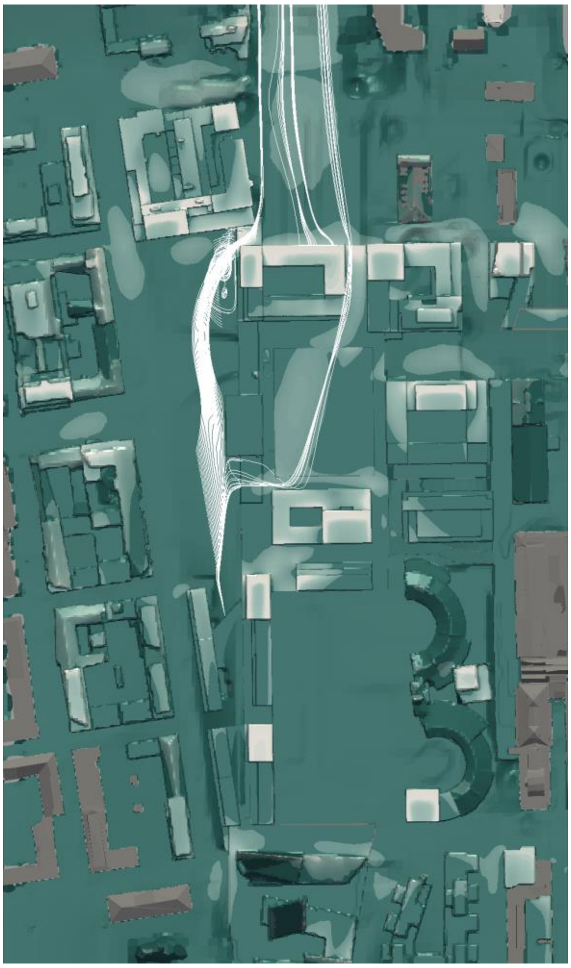


270° (West)



300°


330°


360° (North)