Decoding Urban Nature

Adapting cities for climate change

Urban areas are home to millions of people who are exposed to the climatological conditions of their environment every day. In order to create sustainable living conditions for them, minimisation of heat stress, air pollution and wind risk should be a core topic for politicians, architects and urban planners – especially when environmental conditions threaten health. Our mission is therefore to help building more livable urban areas for people and plants.

Sustainability is often considered as a compromise between people's needs and the needs of the environment. However, we show in numbers that the contrary is true.

It is just a case of understanding the dynamics of the local environment to enable sustainable designs. We do this by investigating and quantifying the effects of architectural and urban planning on the microclimate of outdoor spaces with our ENVI_MET simulation software.

Our system is based on a high-resolution numerical simulation of the urban environment using the latest scientific approaches in thermodynamics, fluid simulation and tree physiology. In the complex world of outdoor environments, climate parameters, vegetation, surfaces and structures constantly interact with each other. Due to the resulting interdependencies, these elements cannot be viewed in isolation or be analysed independently of one another. For an adequate simulation of such an environment and its feedback processes, it is vital to integrate all the interacting elements into one system, even if only a single climatological aspect such as air temperature is required.

To meet these challenges, ENVI_MET uses an unmatched and unique holistic approach in which all the different aspects of a microclimate are linked and simulated together in one complex model that ensures an all-encompassing analysis.

Daniela Bruse, CEO ENVI_MET
July, 2017

About ENVI_MET

ENVI_MET is a holistic microclimate model, in which all the different elements of an urban or landscape setting interact which each other. The initial version of ENVI_MET was designed back in 1994. Since then the model has been constantly developed, always considering the latest simulation techniques and making the most of computer technology advances.

The models' calculation modules span over a wide range of different scientific disciplines from fluid dynamics over thermodynamics to plant physiology or soil science. It is the heart of the ENVI_MET model philosophy to integrate all these different approaches into a single model so that all elements can interact with each other and reproduce the synergies we can observe in the real.

This holistic approach makes ENVI_MET different to other models for environmental simulation. There are many models which calculate the air flow between buildings or the solar input on facades, but there are only very few, if any, that see the whole system in one picture and consider the multitude of processes that take place between the elements.

Areas of application

Solar analysis:

- Sun & shade hours
- Glazing analysis
- Shadow casting
- Solar energy gain

Green & blue technologies:

- Benefits of façade & rooftop greening
- Impact of green spaces and water
- Simulation of Living walls

Pollutant dispersion:

- Release, transport and deposition of particles & gases
- Chemical reactions in the air

About us

Passionate and driven by the desire to understand and simulate our environment as a holistic organism, we wanted to develop a climate software that works with objective scientific methods so that measurable and sustainable actions on climate change are possible. Our vision is therefore to prove the beneficial effects of green architectural designs, green & blue technologies and landscape architecture for outdoor climates all over the world.

There are many companies that will tell you that they do what we do. But the reason why the ENVI_MET software has become one of the leading simulation tools when addressing the impact of architecture and urban planning on the microclimate system, is that it is always a few years ahead of other systems, setting new standards in high-resolution climate modeling.

Moreover, as the designers of ENVI_MET, we can offer you a wide range of specialised and personalised simulation modules matching your individual design idea. This ensures that you get the best out of your design and project visions. So – besides the license sale of our software – we also work worldwide with our ENVI_MET EXPERT package for academic, civic, residential and commercial property clients.

Wind flow and Turbulence:

- Wind patterns in complex environments
- Wind speed at buildings and trees
- Wind comfort

Microclimate and Thermal Comfort:

- Outdoor thermal comfort for humans and plants

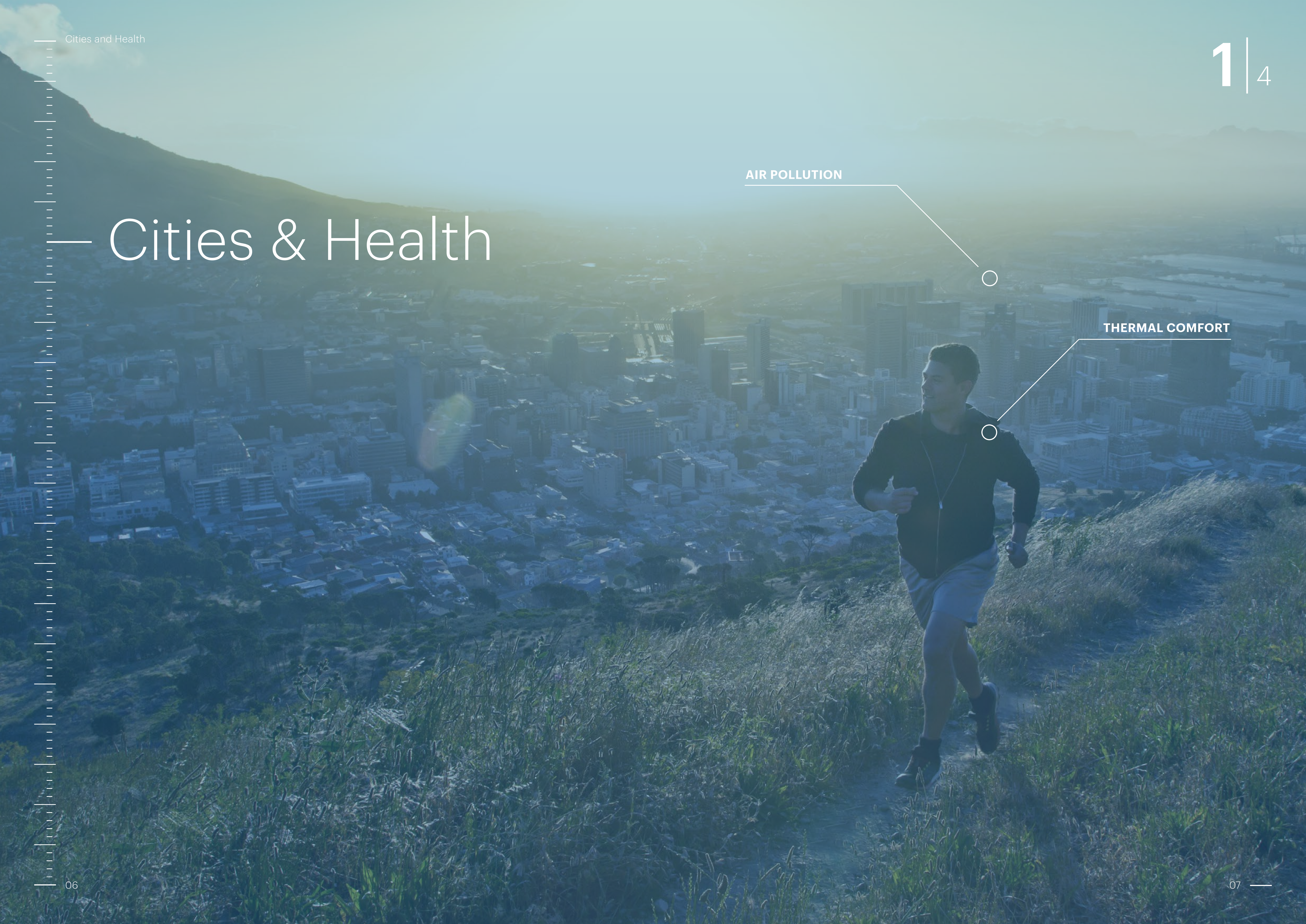
Building physics:

- Façade temperatures
- Interaction of outdoor microclimate with indoor climate
- Energy exchange with outdoor environment

Tree-Pass:

- Analysis of plant growing conditions
- Tree wind stress diagnostics
- Water usage simulation

Cities & Health



Air pollution

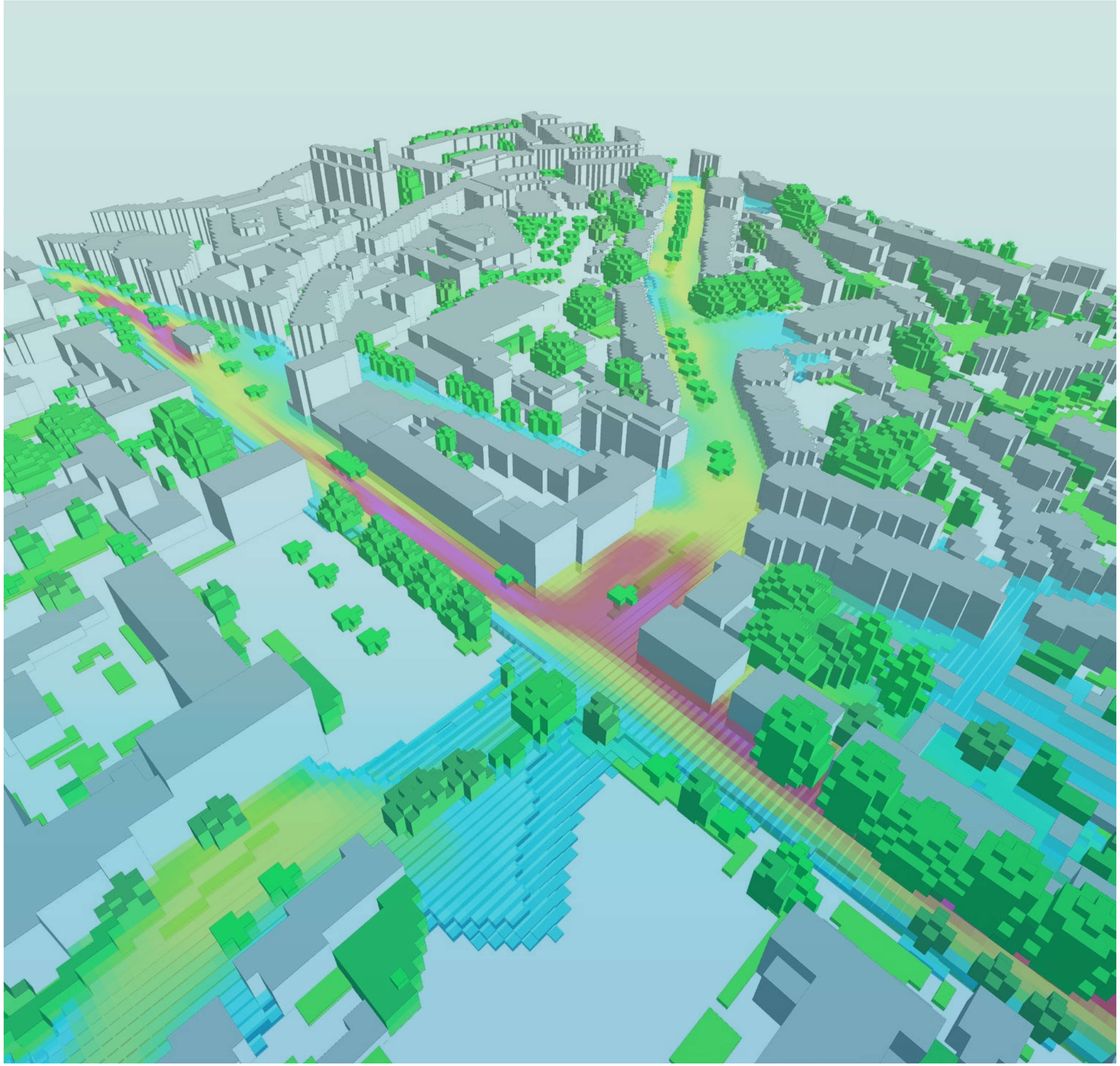
It is common sense that clean air is essential for the well-being of humans, animals and plants. But high traffic density, fuel combustion, biomass burning and industries are creating a mixture of air pollutants that are major risk to health.

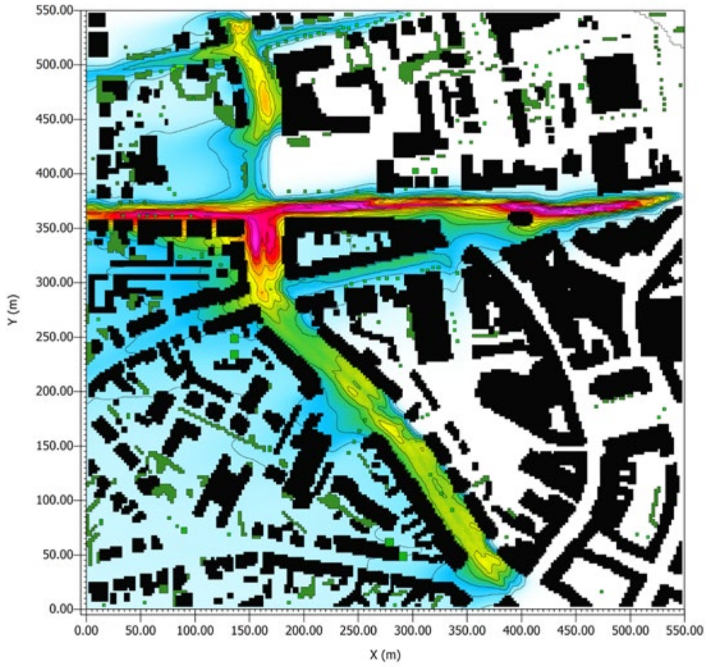
China tops the WHO list for deadly outdoor air pollution so far, but also in Europe there are nearly 500,000 premature deaths each year. Decades of industrialisation and rapid economic growth have led several countries to experience air acidification, harming vegetation and buildings.

Even when the emission situation is not that severe, the combination of pollutant sources and poorly aerated areas such as narrow street canyons can quickly lead to the accumulation and local enrichment of air pollutants in excess of air quality standards. Moreover, it is known that even low pollutant concentrations can increase allergic responses e.g. to pollens.

The pollutant dispersion model of ENVI_MET allows the synchronous release, dispersion and deposition of up to six different pollutants including particles and both passive and reactive gases. Sedimentation and deposition on surfaces and vegetation is taken into account as well as the photochemical reaction between NO, NO_2 and Ozone (O_3) and the release of (B)VOC through plants.

The results can be used to better understand the dynamics of local pollutant dispersion and help to develop urban streetscapes and green infrastructure for improving air quality and human well-being.

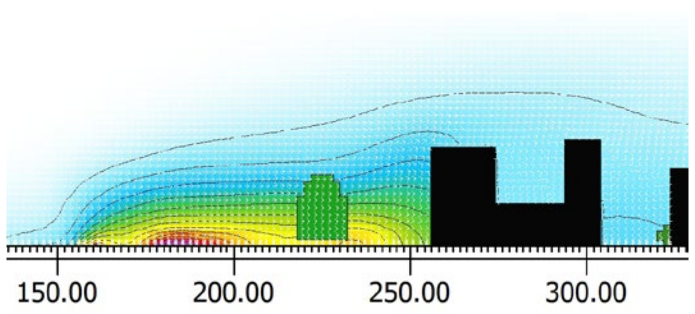




Distribution of NO in an urban CBD area

Air quality conditions can vary highly in urban areas.

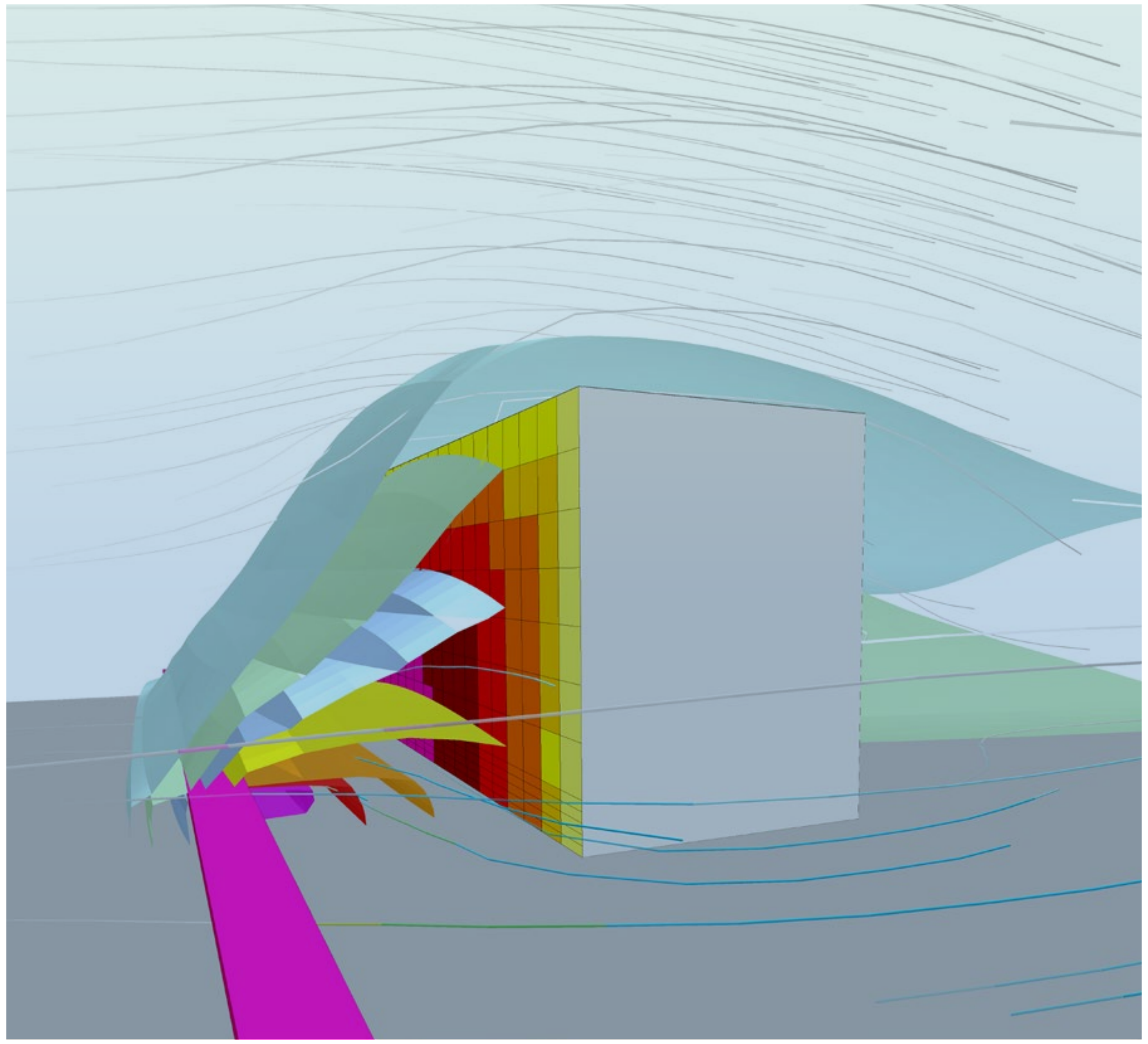
In urban areas, traffic is the largest source of pollutants in the air. Pollutants such as particulate matters (PM) or chemically active gases such as NO and NO_2 are massive health threats to citizens, animals and plants. Through wind transport, airborne pollutants can travel several hundreds of meters or more causing emission loads far away from the original source. To understand and improve the transport and dispersion of pollutants, an integrated modelling analysis is required. This includes the calculation of the complex urban wind field, the chemical conversion of pollutants, and the consideration of deposition processes on plants and surfaces.



Dispersion of particulate matters PM10 through a vegetation barrier

Vegetation is an effective but complex tool to control air quality

Vegetation elements such as trees, hedges and green façades are tools to control pollutant distribution. But the interactions between green elements and air flow, turbulence and pollutant deposition form a highly complex and interactive system that cannot be assessed by rule of thumb. Through the interactive coupling of the pollutant dispersion modelling with the high-resolution vegetation model, ENVI_MET allows an estimation of the benefits of even complex nature-based solutions to manage air quality.



Dispersion of of particles from a road and resulting concentration on building façade

Indoor and outdoor air quality are directly linked through microclimate

Many people think of air pollution as a purely outdoor problem. But if windows are opened or air conditioning takes air from the outside, outdoor pollutants are transported into the indoor environment. Whether you will receive fresh air or air pollutants when you open your window depends on the microscale wind patterns around the building. ENVI_MET allows the analysis of wind flow and pollutant transport for each façade segment of a building down to a resolution of one metre.

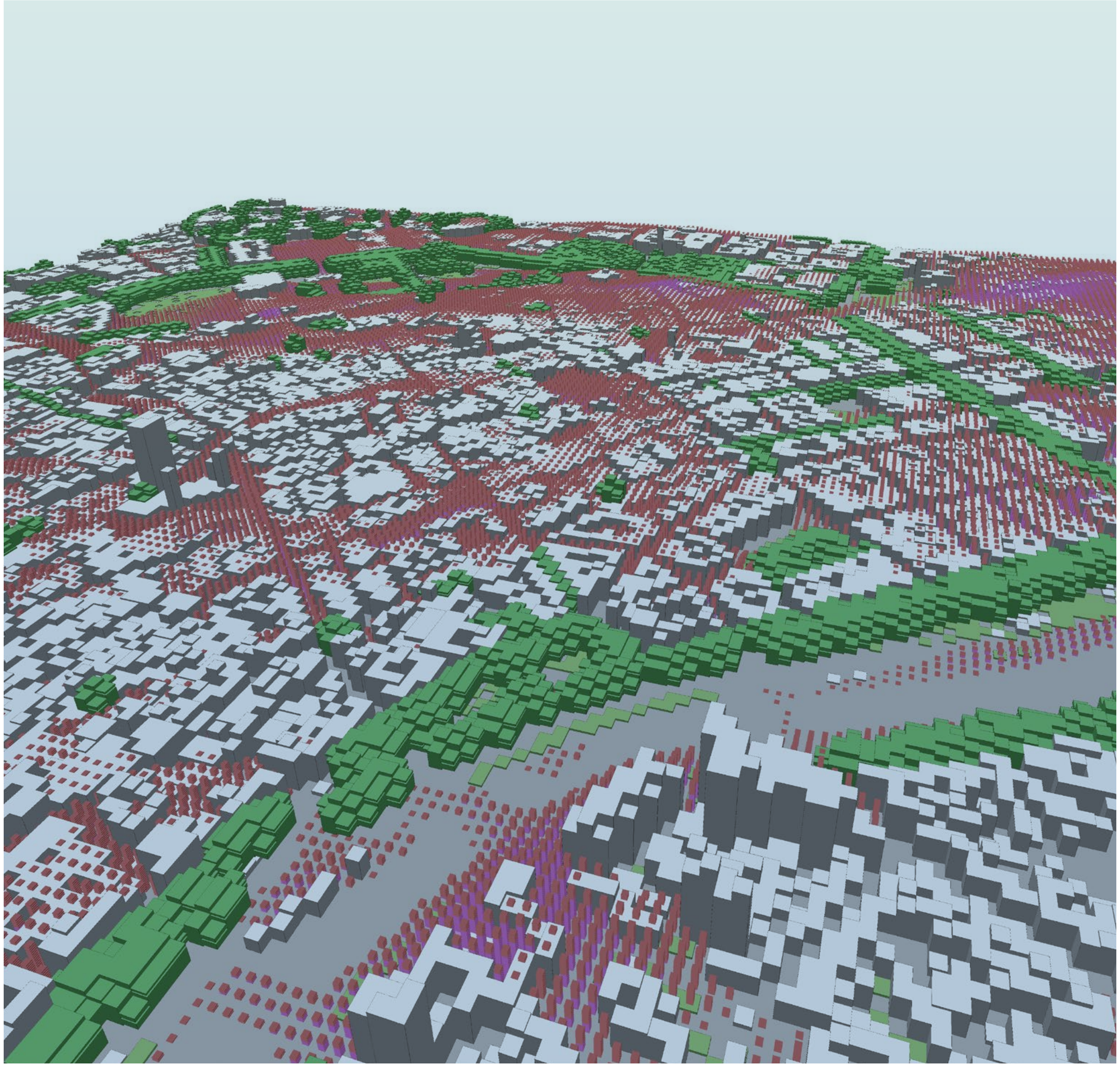
Thermal comfort

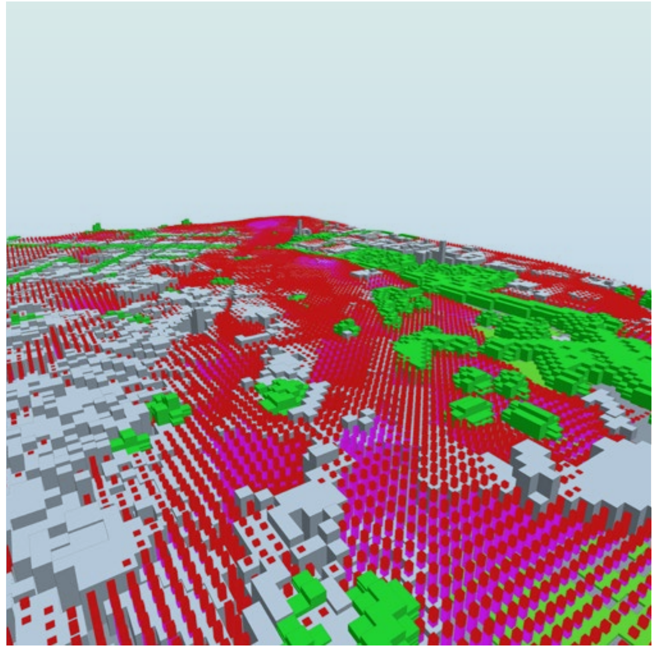
In the context of urban microclimates, thermal comfort is the key indicator to describe people's subjective experience of temperature in open spaces. It summarises the impact of sun, wind, air temperature and humidity on thermal sensation.

If the human body is not able to compensate for hot or cold environmental conditions through thermoregulation, thermal discomfort arises and the actual environment is perceived to be too warm or too cold. Unpleasant thermal conditions in urban areas are one of the main reasons why people prefer to live in the outskirts of the city rather than in the centre. This leads to a continuous expansion of urbanised areas, known as urban sprawl. There are many environmental and economic drawbacks associated with this sprawl effect, of which land consumption and traffic congestion are probably the most obvious.

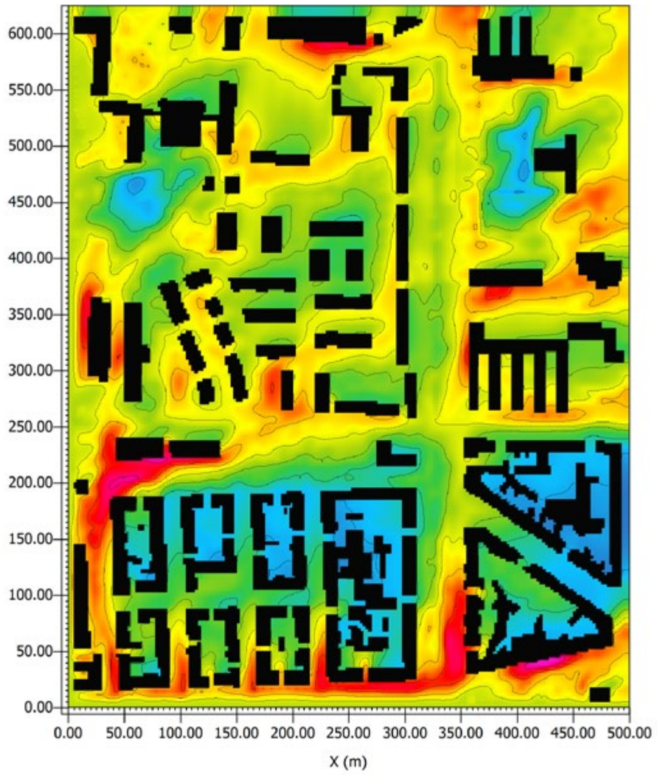
Sustainable urban open spaces must therefore have a design where the expectations and wishes of the potential users meet with the functional requirements of the city structure. Hence, assessing the microclimate conditions of an urban space means finding out how pedestrians feel under given climatic conditions – especially their thermal and wind comfort – and how this affects the behaviour within the urban structure.

In addition, adequate thermal conditions can play a key role in the economic success of outdoor facilities such as cafés, shopping streets or recreational areas. Different thermo-dynamic models in ENVI_MET allow a holistic evaluation of steady state and transient thermal comfort conditions.





Distribution of overheated urban areas in Vienna, Austria at district level in the afternoon



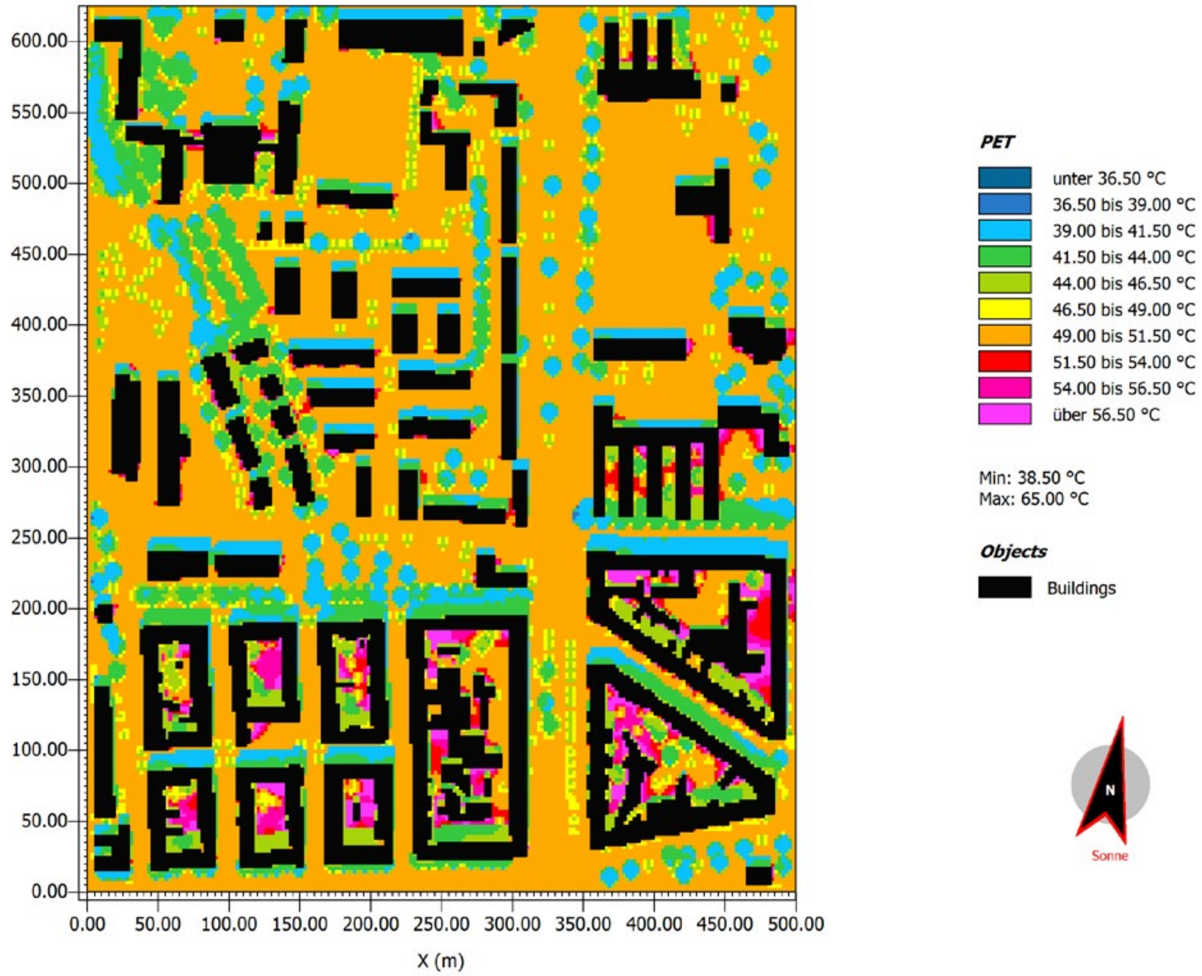
Distribution of air temperature at neighborhood level at 14:00

Analysing the urban heat island

The urban heat island is a phenomenon that can range from small hot spots in a street neighborhood up to complete quarters of the city. To understand the thermal performance of a city by block or at district level, a holistic and dynamic simulation of all causal elements of the urban heat island must be performed. These elements include surface and wall temperatures, wind flow patterns, transpiration of vegetation or the soil wetness. As all elements are considered in the simulation process, the urban system can be analysed from a multitude of perspectives be they building physics, health of vegetation or human thermal comfort, all using the same simulation results. ENVI_MET provides a number of interactive tools to assist the user in big data analysis and visualisation.

Urban neighbourhoods are a patchwork of different microclimates

The multitude of different materials, buildings and vegetation builds a patchwork of very different microclimate conditions within close range of each other. Shaded backyards and urban parks can provide cool pockets and recreational areas even under hot summer conditions. To understand and analyse the impact of redesign and heat mitigation strategies, a continuous simulation of least 24 hours must run to capture all the different heating and cooling effects in an urban area.



Distribution of physiological equivalent temperature (PET) at 13:00

What the microclimate means for humans: calculating thermal comfort indicators

Thermal perception of the environment is driven by meteorological parameters such as wind, solar and thermal radiation, air temperature and air humidity. To understand how humans feel under given thermal conditions, biometeorological models that combine the outdoor conditions with the human thermoregulatory system are applied. One of these is the physiological equivalent temperature (PET) shown in the picture that is calculated using ENVI_MET Biomet. PET relates an outdoor condition to an imaginary indoor situation in which a room temperature of PET will result in the same thermal experience as the outdoor condition analysed.

Wind & Sun

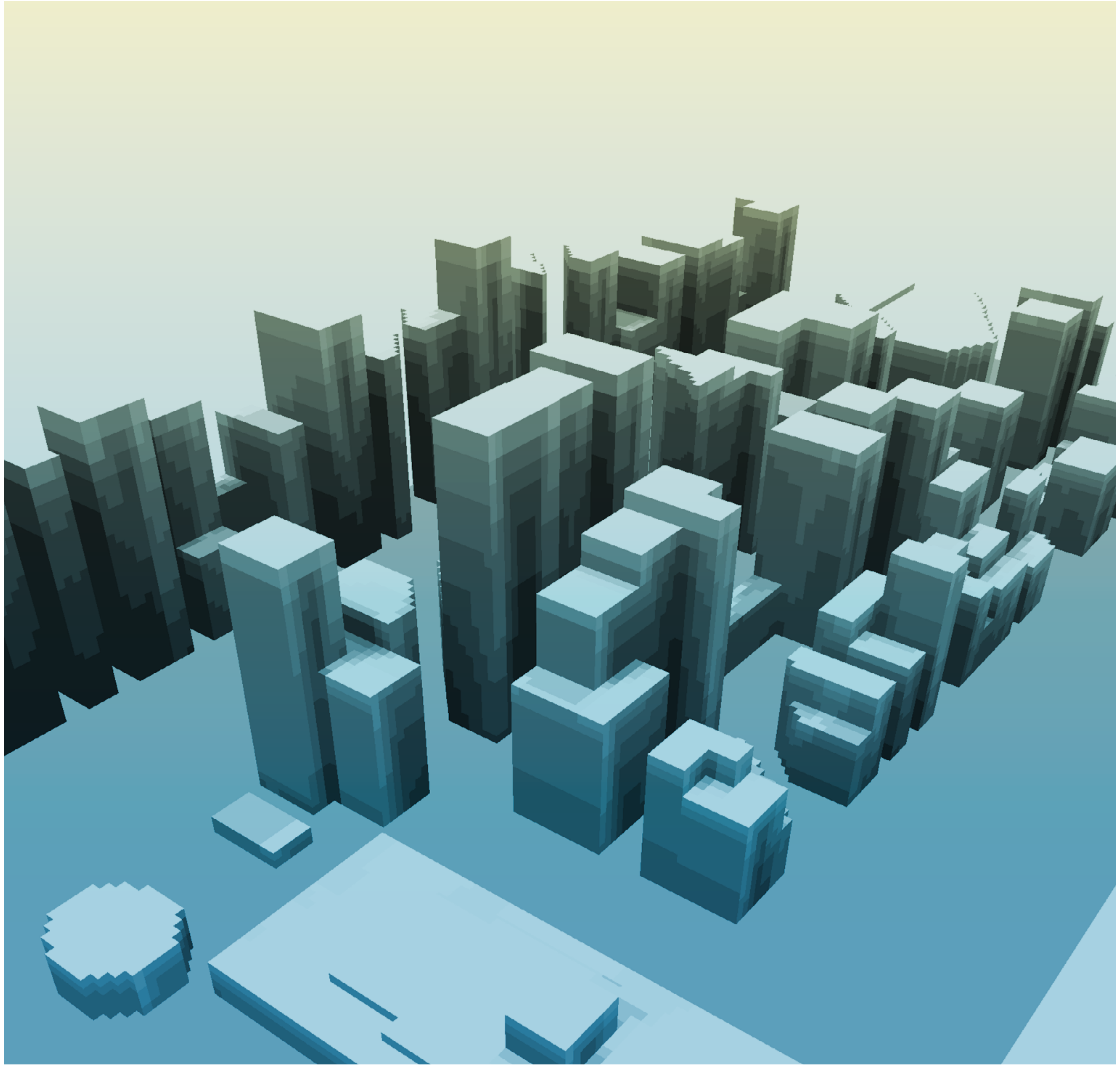
Solar radiation

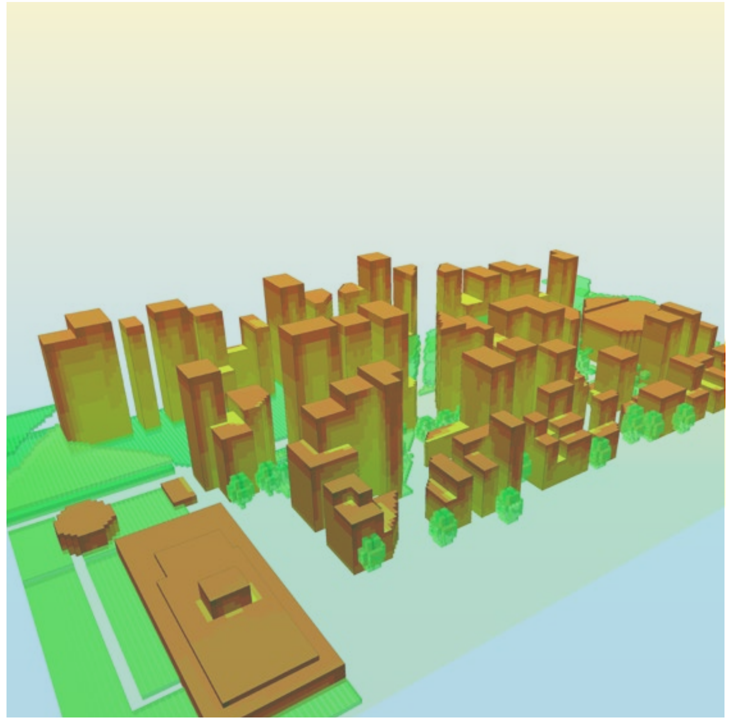
The urban heat island effect, in which an urban area is markedly warmer than surrounding non-urban areas, will likely increase in coming decades. Although urbanisation is predicted to increase dramatically within the next 30 years, this trend has still not been included in many climate model projections and is rarely factored into the criteria of planning and design processes.

In most countries, the summer climate is affected by urban heat, humidity and high solar radiation. The sunlight that hits the built-up areas is often absorbed by dark, non-reflective surfaces which release the heat into the local environment. In addition, low wind speeds in summertime contribute significantly to an increased intensity of urban heat.

From all microclimate elements, solar radiation is the component with the highest spatial and temporal variation within urban areas. Shading from buildings and other elements on the one hand – and the reflection of radiation on bright or glassy facades on the other – can create complex patterns of radiation fluxes. So, understanding and analysing local exposure to solar radiation and daylight over the year is essential for all urban and architectural planning processes. Both too much and too little access to sunlight can lead to uncomfortable living conditions for both humans and plants in indoor and outdoor spaces.

ENVI_MET provides sophisticated three-dimensional analysis tools to calculate and trace the distribution of short-wave direct, diffuse and reflected solar radiation within the outdoor environment. In contrast to other software programs that allow the simulation of radiation fluxes, ENVI_MET can also simulate airflow, heat and vapour exchange in urban areas, with a high temporal and spatial resolution using the same input data as for the solar analysis.



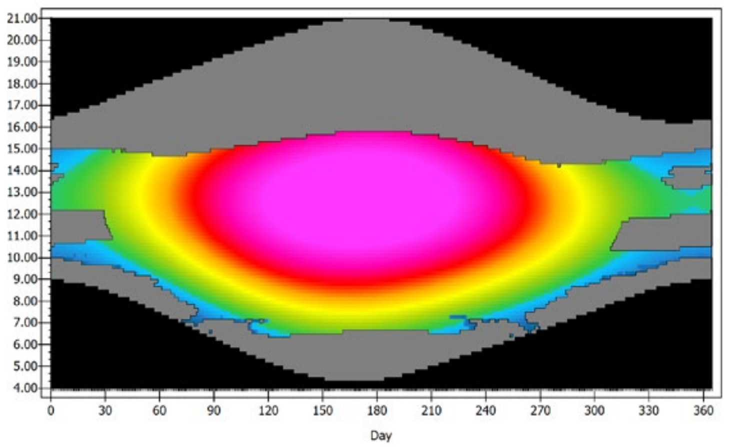


Potential sun hours on façades and roof tops on a summer day

To design buildings with the sun means finding the balance between too much and too little radiation.

Building façades and roofs represent the largest proportion of sun-exposed surfaces in urban areas. The energy available at the building's outer envelope provides the basic framework for all energy-related processes involving the building, from solar energy harvesting options to cooling demands.

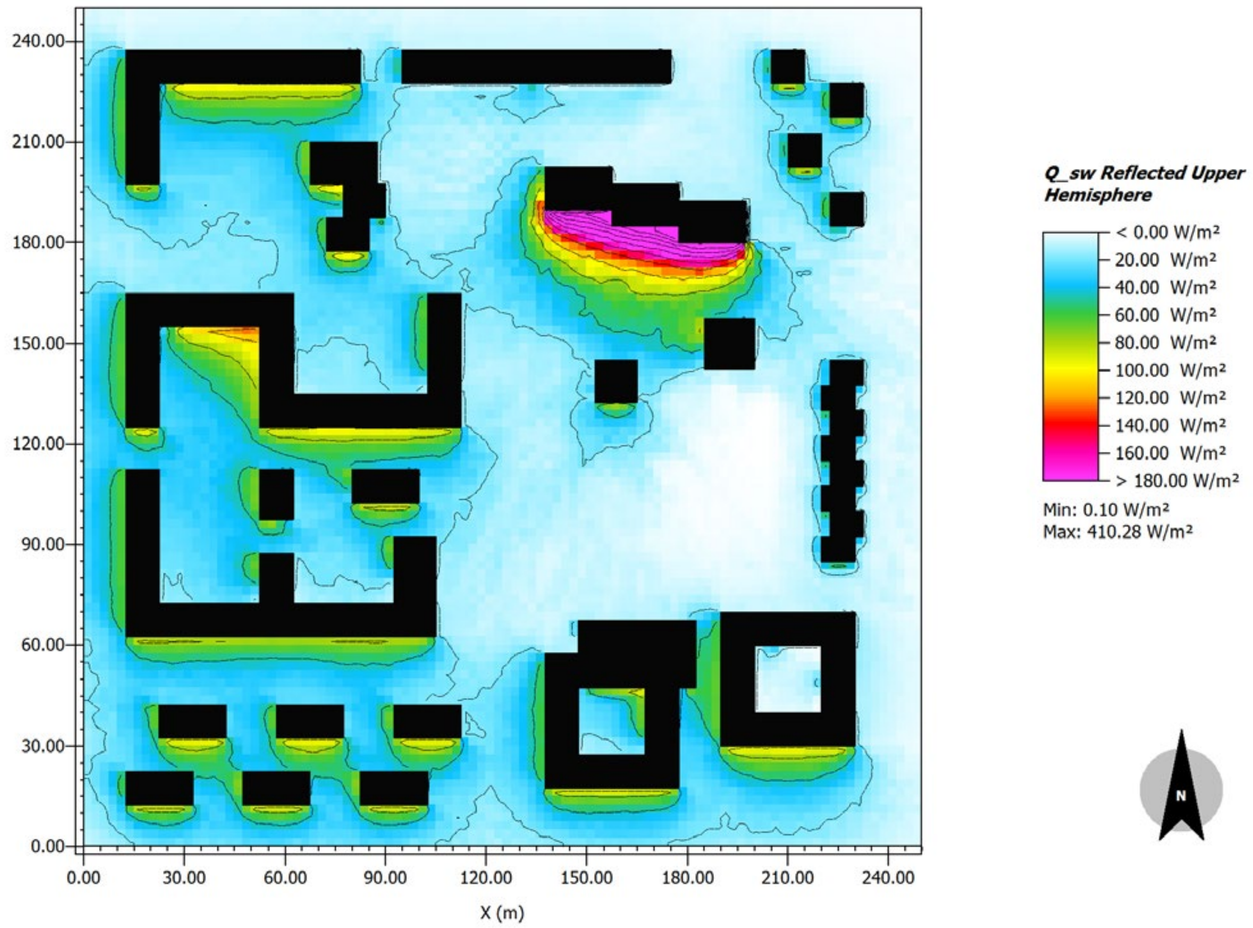
ENVI_MET's solar access modules allow a quick and comprehensive analysis of solar radiation on all building façades taking into account the environment including vegetation.



Analysis of relative local solar access throughout the year

Solargrams: A quick overview of solar access all throughout the year

Besides detailed microclimate analysis for time rages from one to several days, ENVI_MET also provides long-term yearly analysis of important climate parameters such as solar access. This allows not only for the estimation of the general energy input at building façades, but also for the quantification of growing conditions for plants all through the year.



Reflected solar radiation calculated with IVS

High resolution modelling of solar radiation in complex environments

The reflection of solar radiation from highly reflective façades made of metal or glass can change the local microclimate significantly. In the picture above, the upper right building has a façade made of aluminum while the other buildings use a standard concrete material. Radiation can increase by 300 W/m^2 or more in the area surrounding highly reflective materials. In ENVI_MET, the Indexed View Sphere (IVS) method allows for high-resolution modelling of radiation fluxes including multiple reflections and exact estimation of thermal radiation.

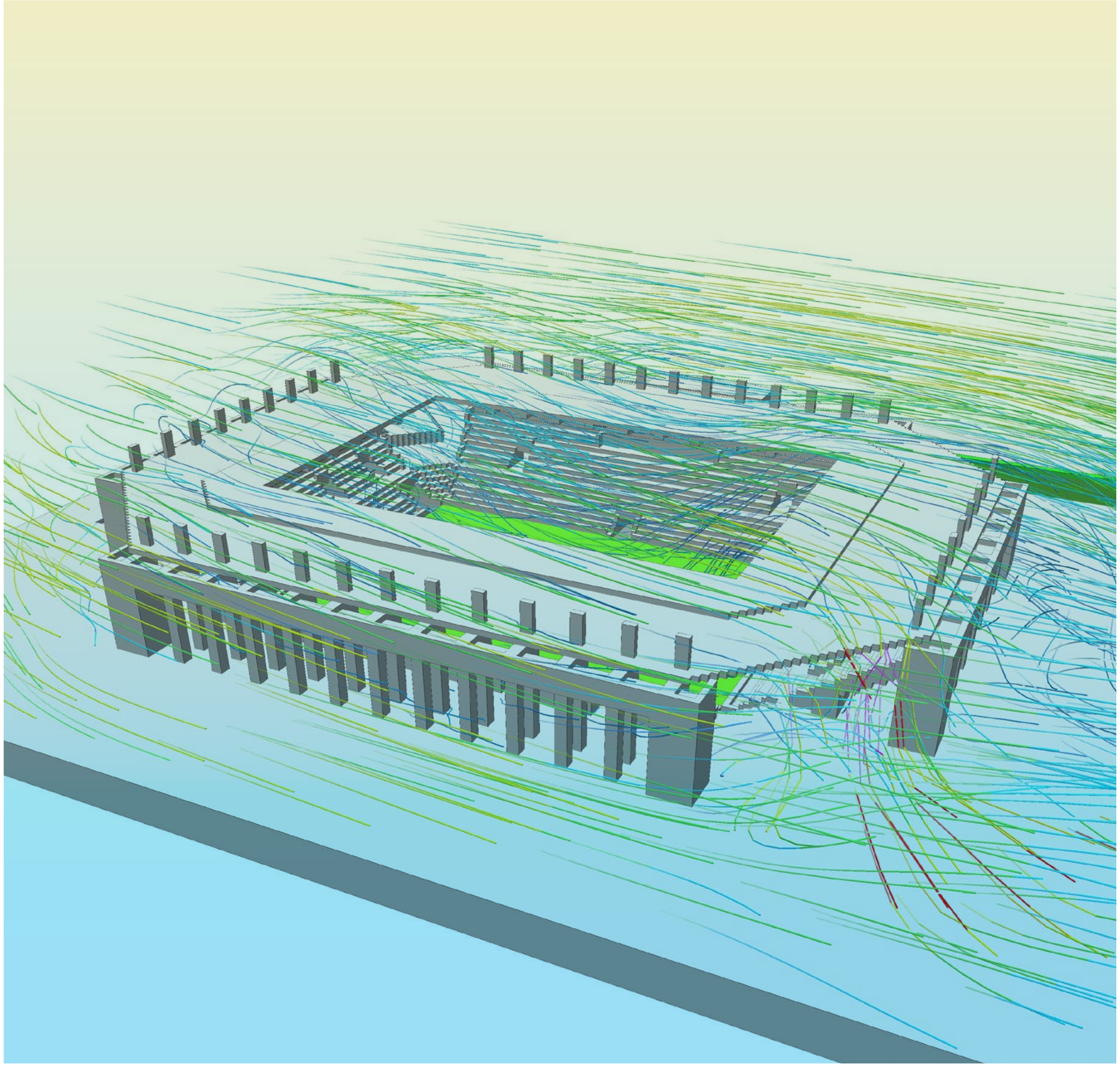
Wind flow

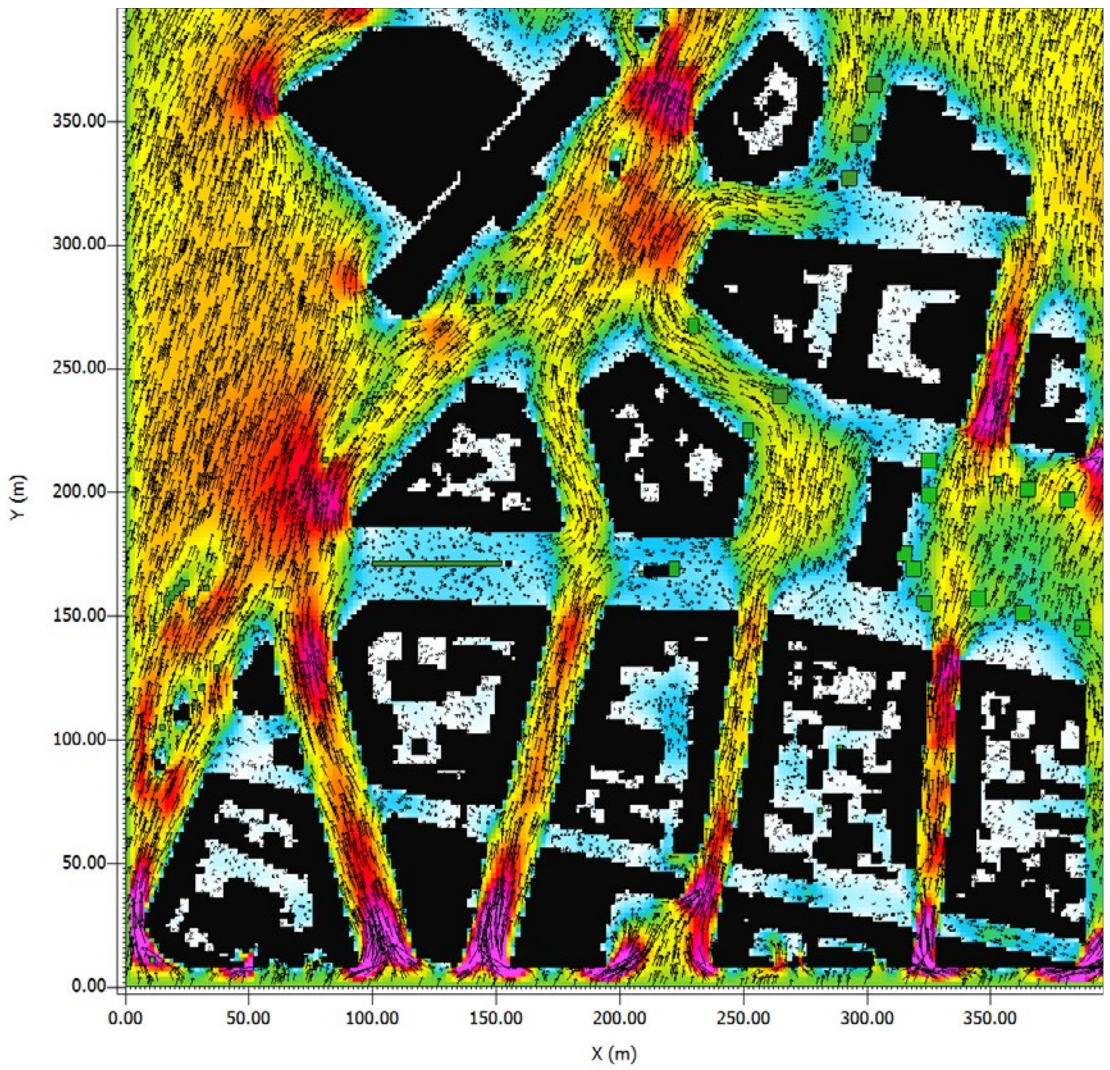
Cities worldwide prepare themselves with different devices to adapt to the negative consequences of climate risks like heat waves, heavy rain and stormy winds. The wind situation differs considerably between urban areas and more open spaces.

Through the three-dimensional structure and disposition of building volumes within cities it is possible to experience areas of high wind speeds and turbulent wind gusts. The opposite situation can be found in the immediate vicinity of those areas. Zones with very low wind speed and stagnating air masses can increase the effect of heat stress, the accumulation of pollutants and promote the development of varmints in vegetation.

Through in-situ measurements it is possible to collect local information on wind speed and direction, but in order to obtain spatially inclusive and comprehensive data, especially when considering future planning scenarios, wind tunnel experiments or computational fluid analysis (CFD) are absolutely essential. Since wind tunnel studies are not only very complex, but can also represent only a few partial aspects of the possible microclimatological conditions, numerical studies have now established themselves as standard in research and practice with the aid of simulation programs.

The ENVI_MET software is the world's only numerical climate model to analyse the interactions between urban development, architecture and landscape architecture as well as the microclimate and air quality down to a scale of one metre. It is thus possible to investigate the interactions between climatological conditions and local environmental design.

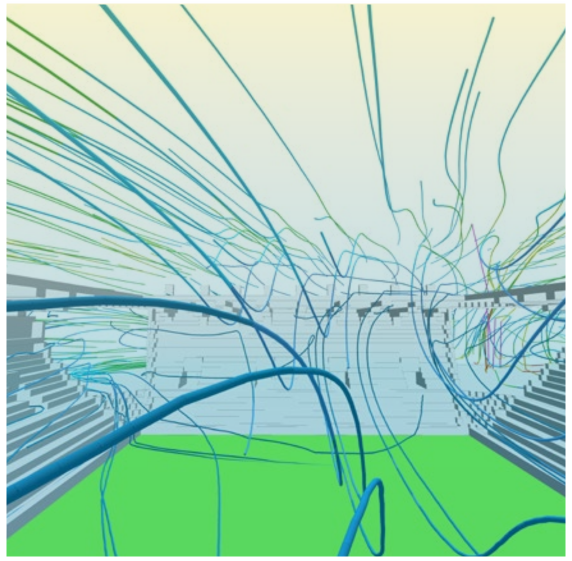




Wind vectors and wind speed at street block level

The wind field determines all exchange process

Simulating the three-dimensional wind field is one of the most important tasks when analysing the urban microclimate and air quality. The wind vector determines not only the transport of energy away from surfaces and the distribution of pollutants, but also the comfort and wind risk for humans and for vegetation. A full three-dimensional system of computational fluid dynamics (CFD) is integrated into ENVI_MET and updated continuously according to changing thermal conditions. Together with an advanced turbulence model, it forms the basis of the microclimate and air quality simulation.

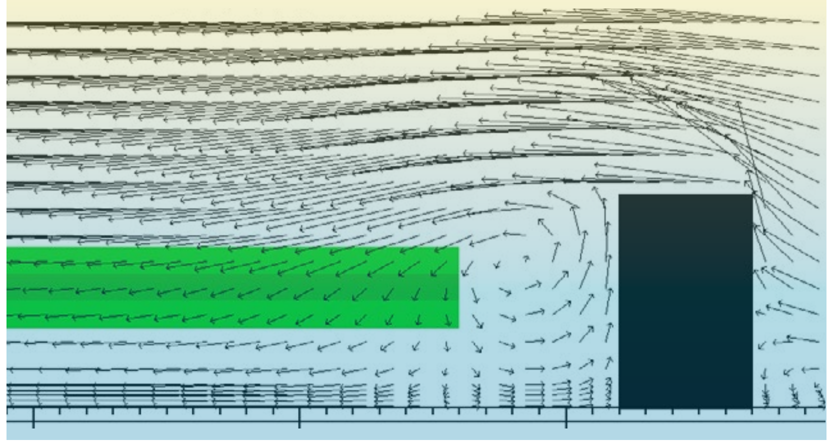


Wind trajectories inside a football stadium

In semi-open spaces, wind is the direct connection between inside and outside

Semi-open spaces like atriums, train stations or the football stadium – shown in the figure to the right – develop a very unique microclimate that is driven by the meteorological situation and the design of the surrounding space.

Wind and sun are the two microclimate elements that establish an immediate connection with the outside environment.

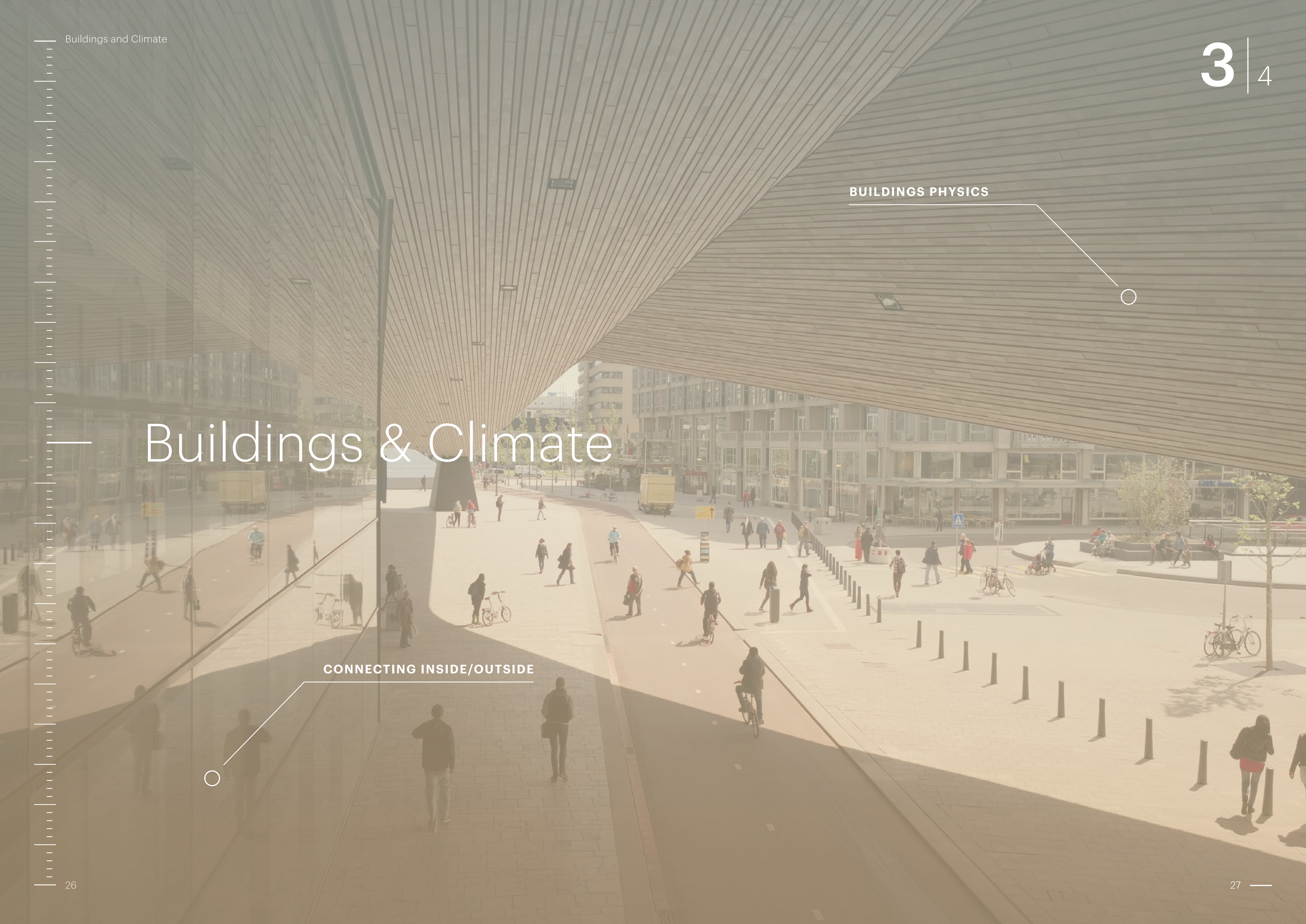


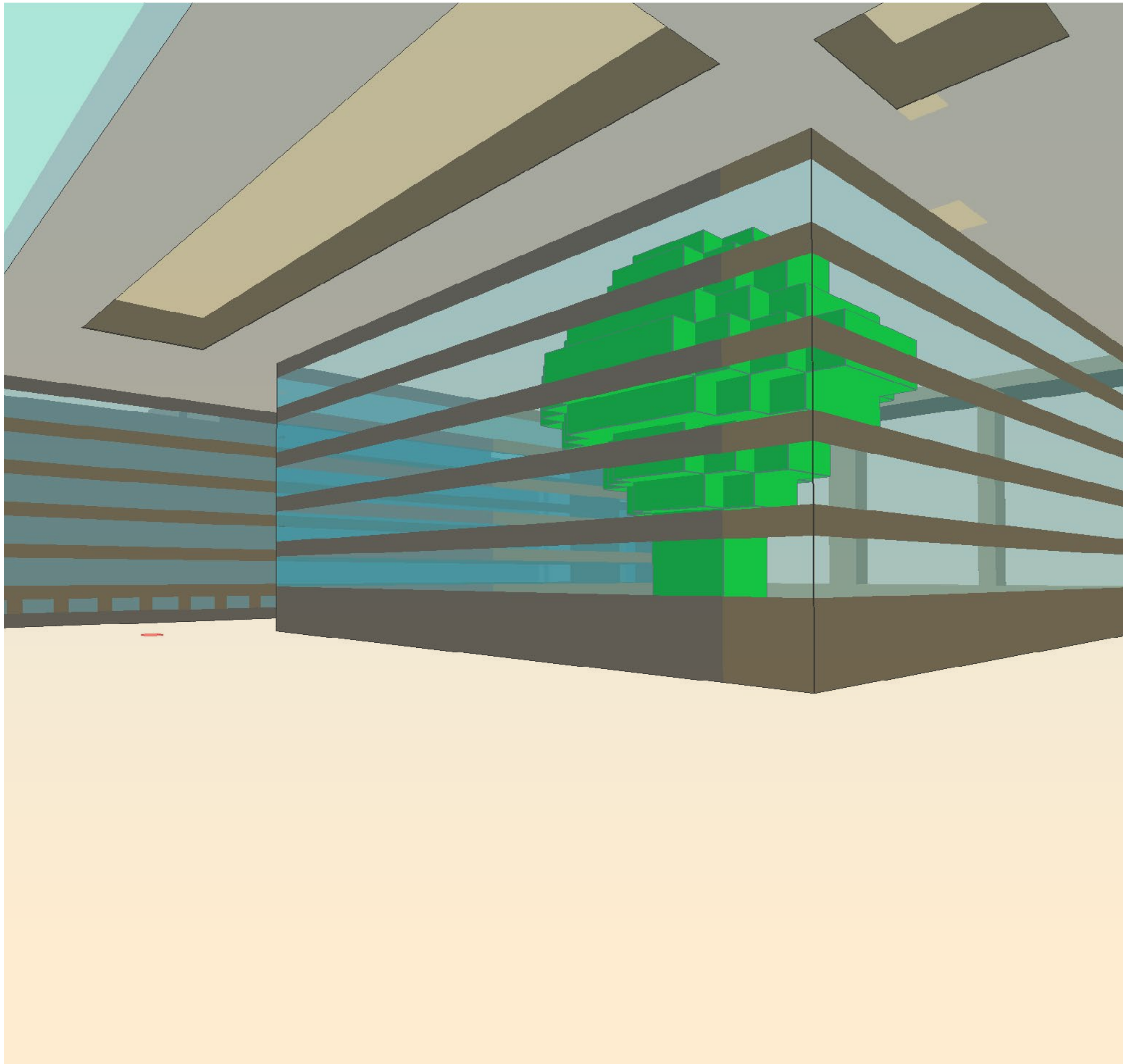
Wind vertex between a row of trees and a building block

Urban microscale wind fields vary within a few meters

The interactions between buildings, vegetation and other elements in the urban space produce highly complex wind patterns than can completely change within a few metres. The figure above shows a typical lee-vertex behind a building. At every single location, we find an individual wind direction and wind speed that drives the turbulence and exchange processes in the proximity of the building and several metres away from the building walls.

Buildings & Climate





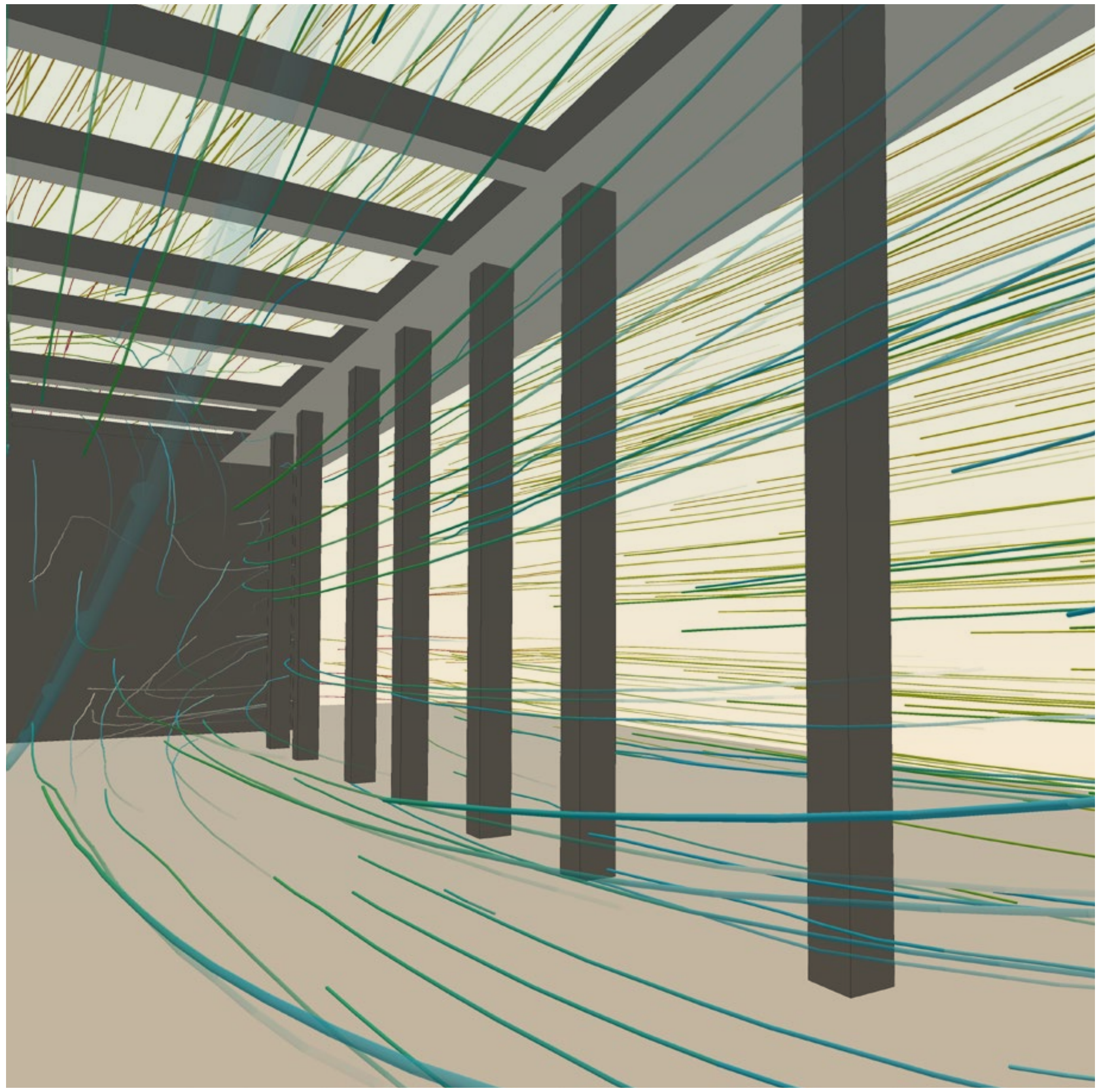
Connecting inside/outside

Buildings are not independent systems, because the indoor climate and the physics of the building interact continuously with the outside microclimate. Moreover, especially in urban areas, the buildings interact with each other through the modification of wind flows, solar access and temperature effects.

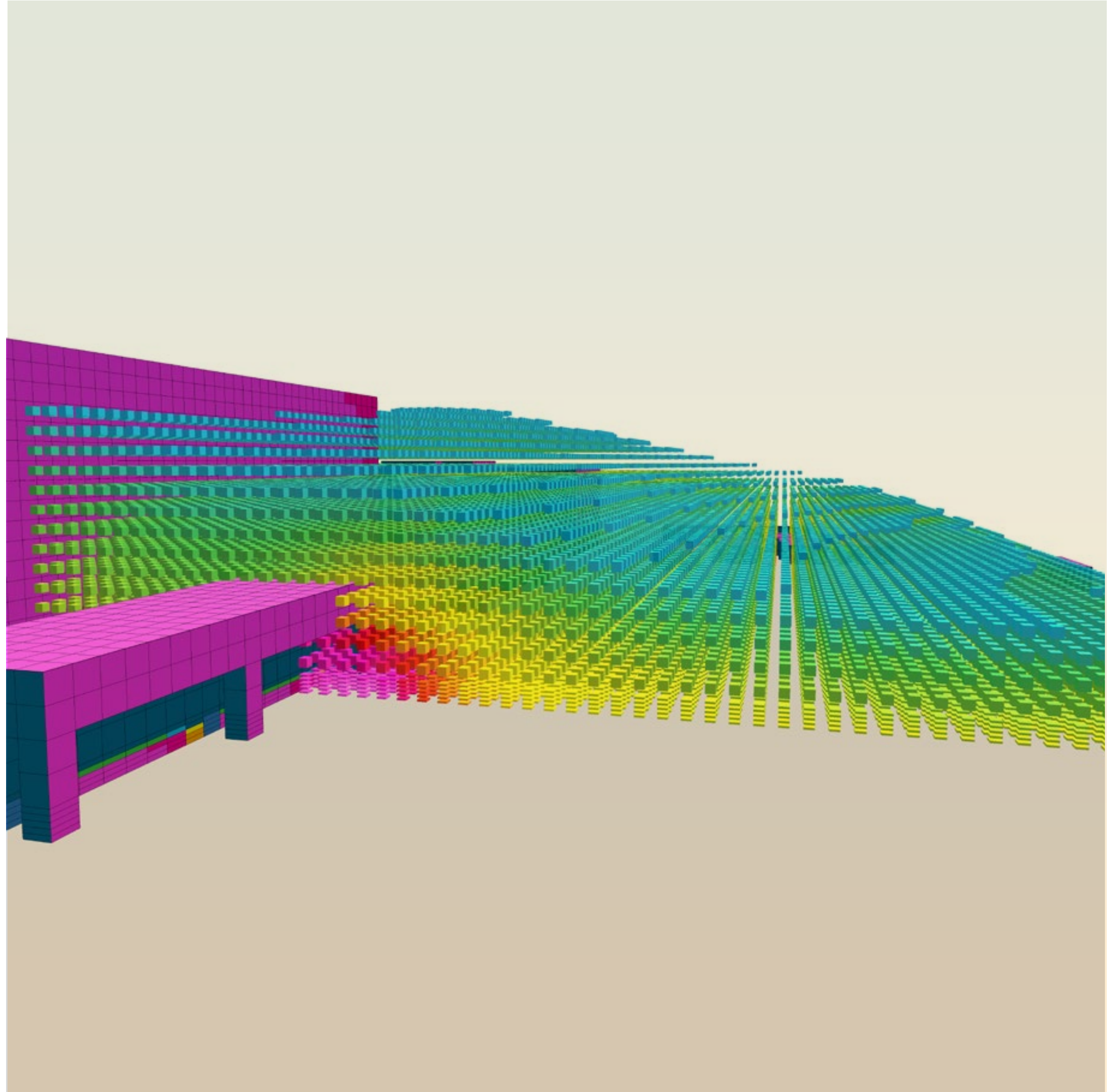
The configuration of buildings, their location and organisation form a unique microclimate at each site. A cluster of buildings, together with urban surroundings such as green areas or traffic infrastructure, form an even more complex and dynamic organism. This includes building materials, surface textures and colours that are exposed to the sun, and the design of open spaces like squares, shopping streets, gardens and roads.

In recent years, new generations of buildings have been developed that are influenced by adaptive materials and constructions that have the ability to react to modifications in their direct or indirect environment.

In order to understand the contribution of individual buildings to the urban microclimate system, and to assess the energy exchange between the interior of the building and the outside microclimate, all elements must be simulated in an integrated simulation framework. The holistic and high-resolution approach of ENVI_MET allows for the simulation of the microscale urban metabolism as a complex system and the energy fluxes at the individual façade element of a single building.



Wind trajectories at the entrance of the German Foreign Office, Berlin



Air temperature and building surface temperature at the Faculty of Geoscience at the University of Mainz, Germany.

At the interface between inside and outside

Most modern buildings are no longer monolithic systems that exist independently from the environment and consume energy to maintain their own metabolism. Today, buildings are designed with awareness of climatic conditions and often allow zones of smooth transitions between the inner parts of the building and the outdoors. To understand the microclimate conditions in these transition zones, the modelling system must factor in the dynamics of both the indoor and the outdoor system. Moreover, as both systems are constantly interacting with and influencing each other, the components should not be analysed independently from each other.

ENVI_MET offers a large set of calculation routines to estimate the energy and exchange conditions at the interface of the open space and the indoor environment.

Does air temperature influence the building's energy or vice versa?

Is the building's energy balance influenced by its surroundings or does the building influence the surroundings? Of course, both scenarios are true. But accounting for this reality in physical formulae is like the "chicken and egg" dilemma.

The only solution is a holistic simulation, in which all processes are influencing each other towards a single solution. The figure above is one such example, where the outdoor air temperature continuously interacts with the semi-open spaces of the building and the façade temperatures.

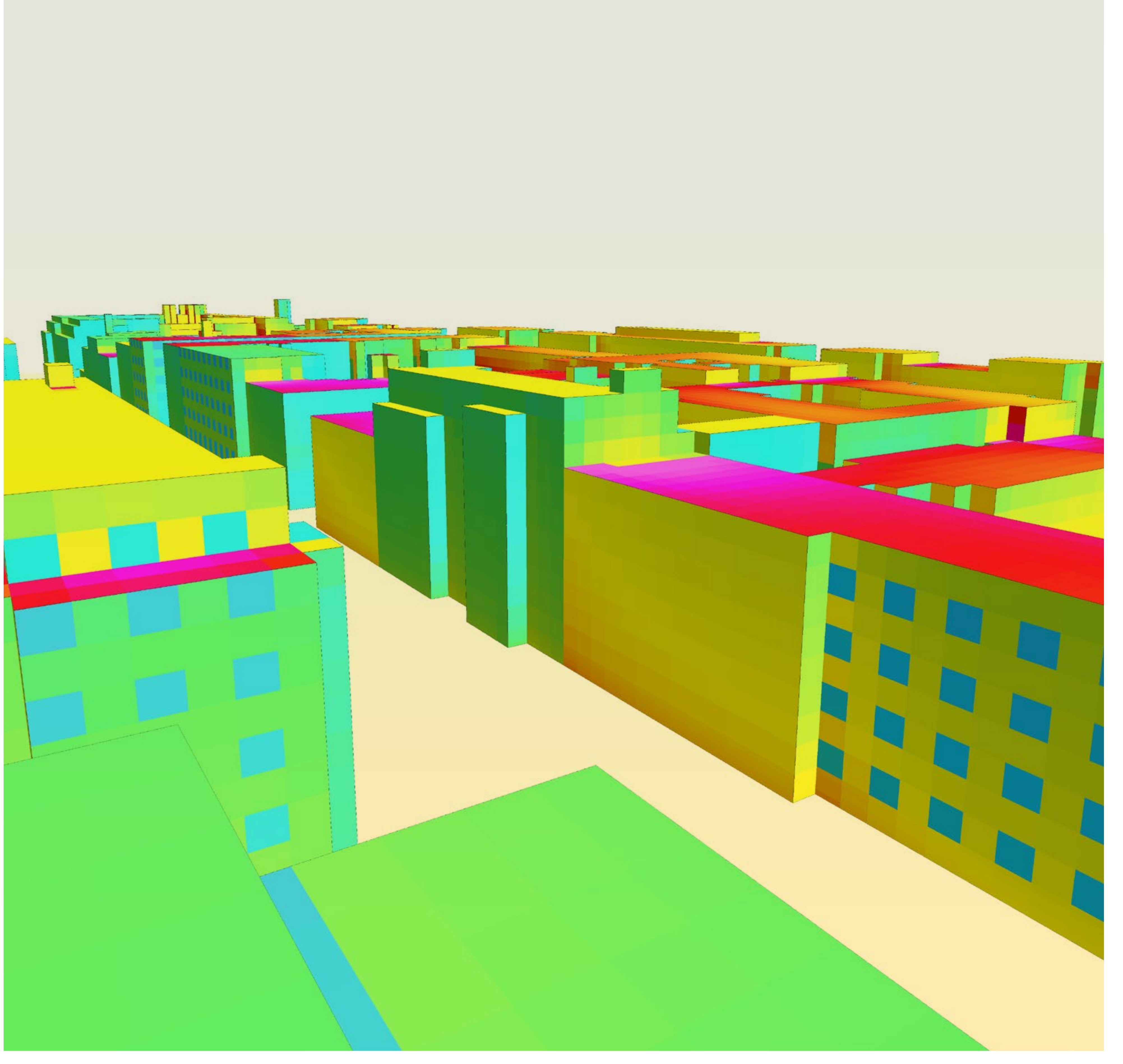
Building physics

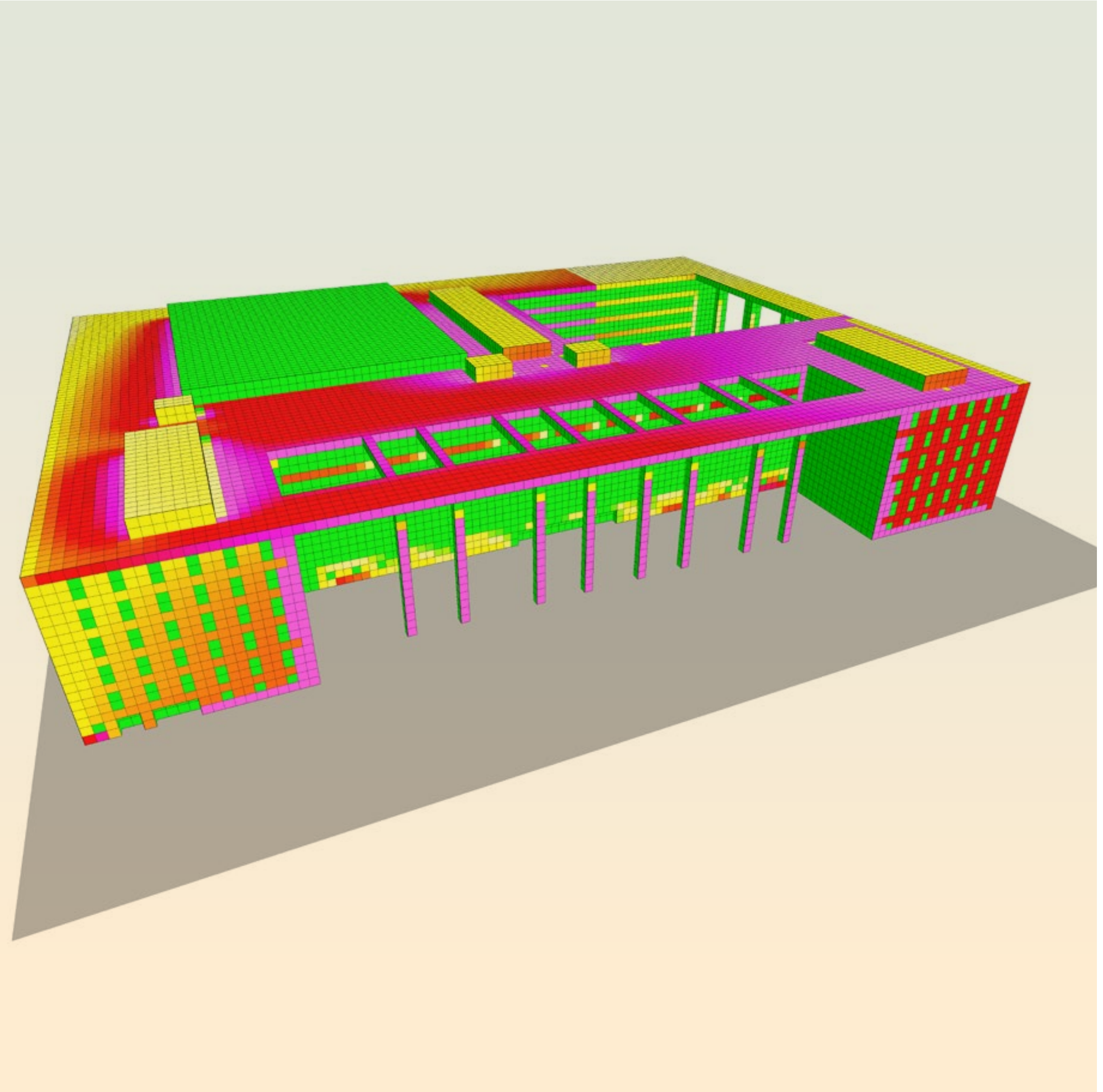
Buildings form the majority of the urban landscape and constitute the interface between the indoor world and the outdoor climate. To understand the dynamics of the urban climate and to analyse its impacts on buildings' energy conditions and consumption, an integrated modelling of the building physics is essential.

The trend towards urbanisation has made it increasingly important to study the impact of urban microclimate on the heat island effect and global warming – as well as the impact on the energy consumption of buildings. In addition, urban comfort, health and longevity of buildings related to pedestrian winds, thermal comfort and pollutant dispersion are of increasing interest to architects and city planners.

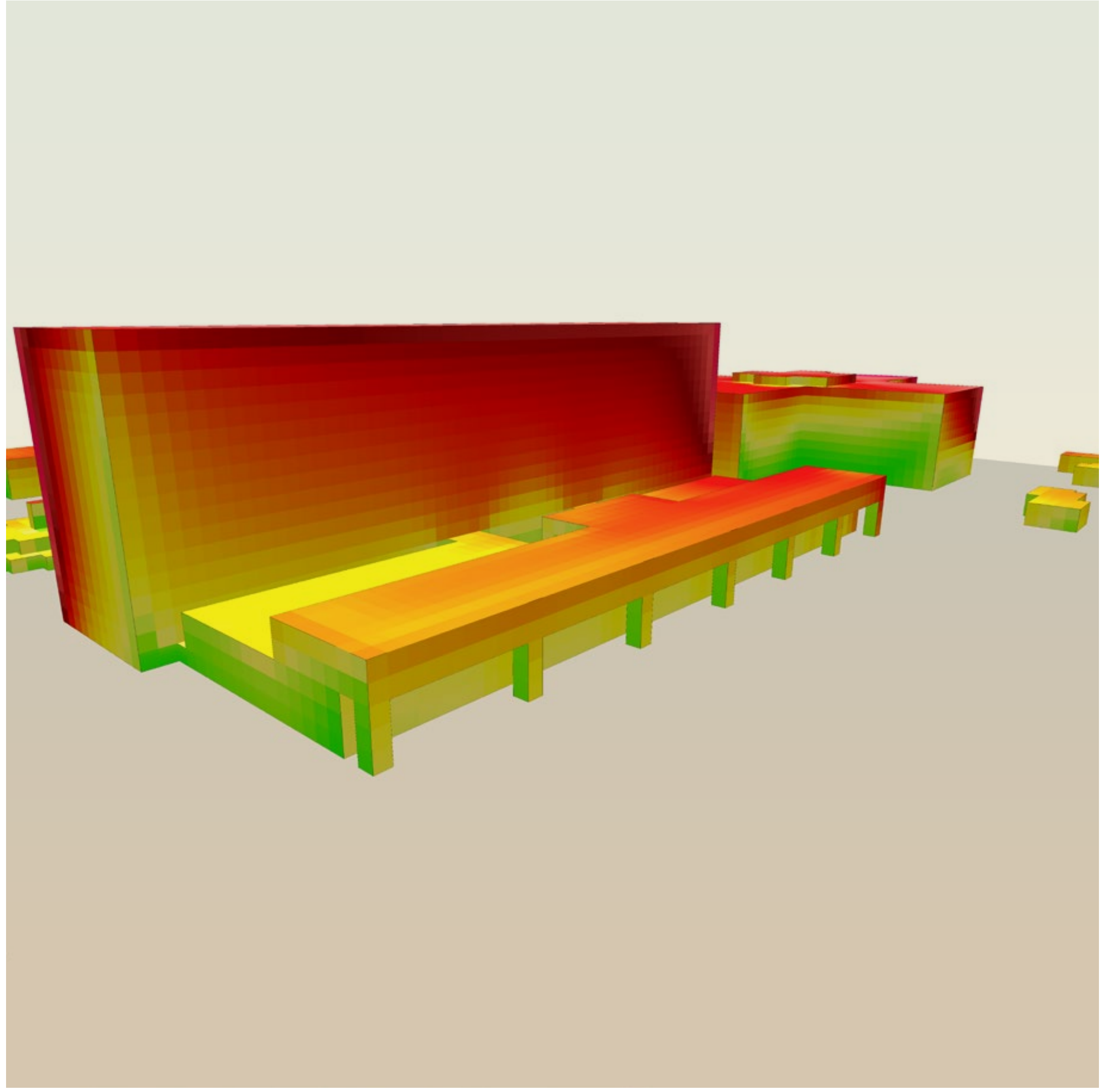
Buildings can be seen as the atomic units of the urban metabolism: the energy exchange processes taking place at their outer envelope modify the local microclimate conditions and form the system we call the urban climate. Conversely, the resulting microclimate system also sets the boundary conditions for the building's inner climate conditions. The more open a building's design, the more it depends on these local conditions to provide reasonable living standards for its inhabitants.

Sustainable urban planning therefore means not only understanding the impact the arrangement of buildings has on the local climate, but also looking at the processes taking place at the single building level.





Façade elements and temperature at the German Foreign Office, Berlin



Wind speed patterns at the Faculty of Geoscience at the University of Mainz, Germany

High resolution simulation of façade temperatures

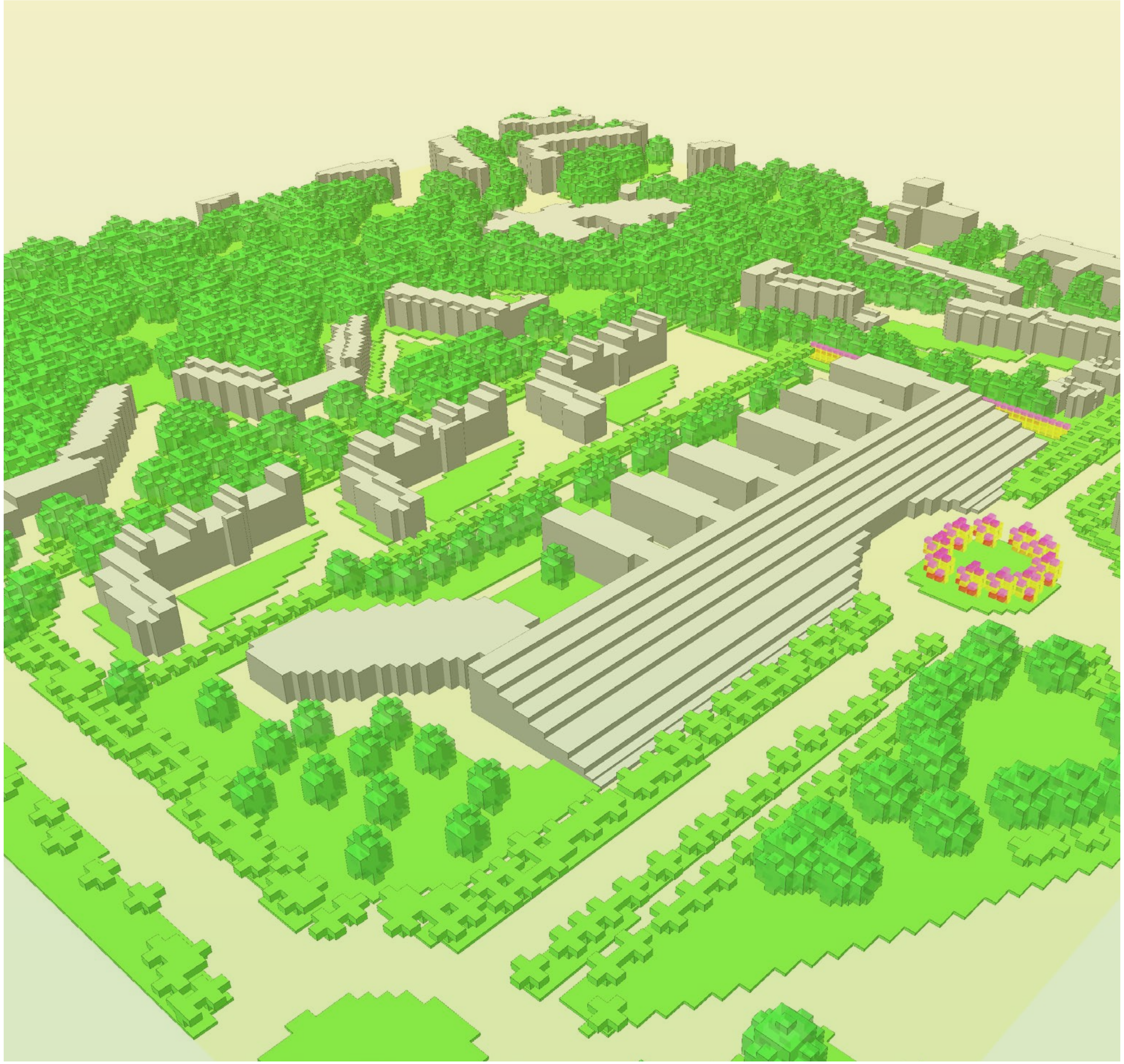
The façade and the roof elements of a building form the interface between the outdoor climate and the indoor building physics. Depending on their material properties – such as insulation, transmissivity or heat conductivity – they decide if the radiation absorbed at the outside will be transported as heat into the inner parts of the building or will remain in the outdoor space. Hence, optimising the energy performance of the building might lead to a decline in the outdoor thermal comfort conditions if all absorbed energy is reradiated as heat.

ENVI_MET analyses the energy performance of each building in the model domain in parallel with the calculation of the outdoor microclimate conditions. That ensures that all feedback processes of the two systems are considered and an optimal solution – with benefits for both the building system and the outdoor microclimate – can be found.

One of main factors for building physics is wind

Wind and sun are the primary factors controlling the thermodynamics of a surface and the distribution of heat. Therefore the ENVI_MET building model is directly coupled to the outdoor fluid dynamics model providing detailed wind data for each second of the day for each wall and façade segment of the building.

Trees & Vegetation



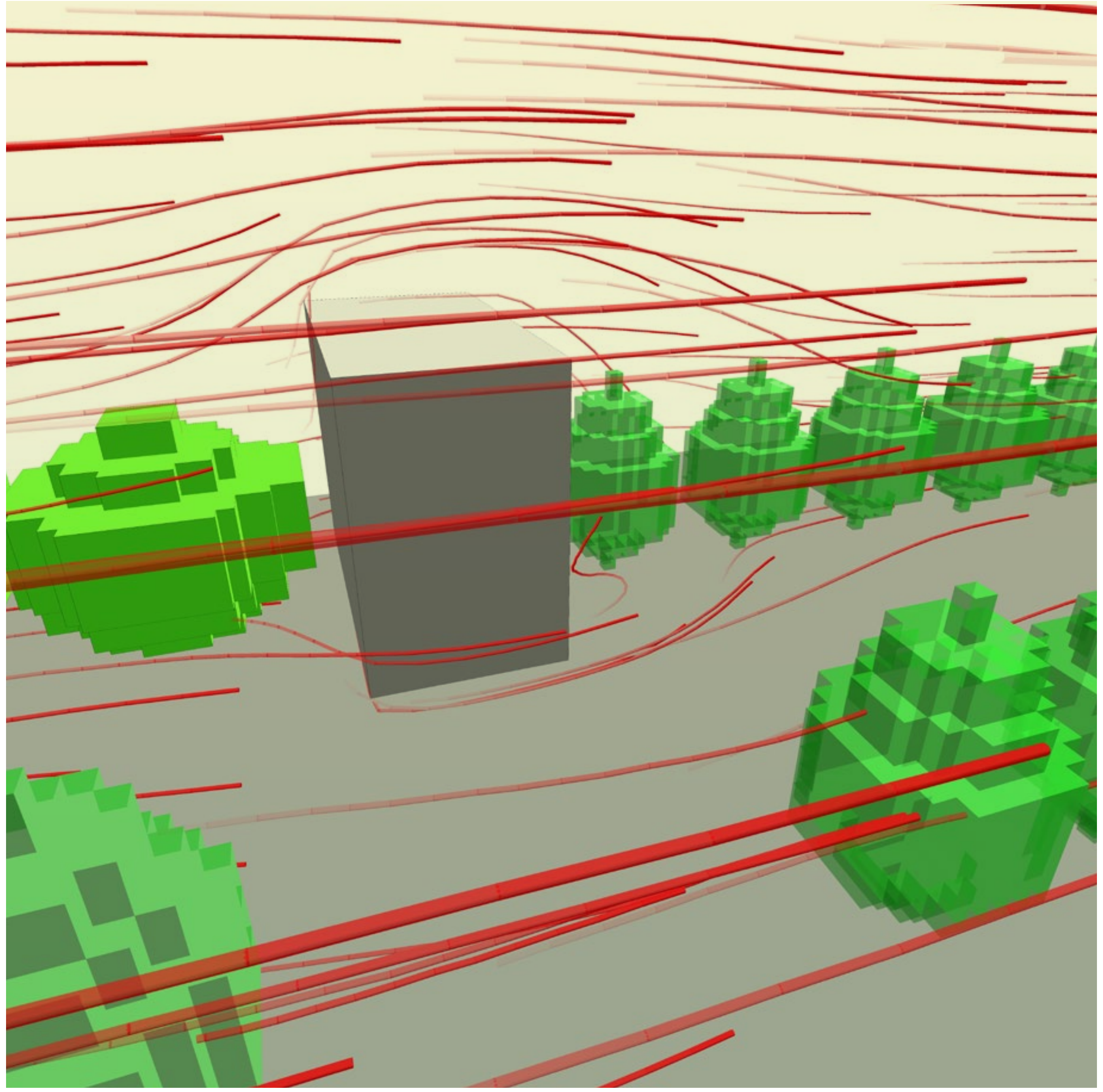
Sustainable Landscape Architecture

In the context of expected climate change, urban and landscape planning face particular challenges. The buffering of heat waves and the handling of severe rain events are the key challenges that are currently being pursued in the context of adapting strategies to climate change. One of the core tools for mitigating negative climate change effects is the use of green infrastructure, in which an increase in urban trees is a key function.

However, plants in general and urban trees in particular are often exposed to hostile conditions in built-up areas. These include, on the one hand, general location conditions such as inadequate space for root systems or soil compaction, and on the other hand extreme climatic conditions caused by the urban structure.

In the urban wind field, acceleration effects can occur due to jet effects and zones of increased turbulence, which can lead to multiple wind loads compared to average conditions. Conversely, often in the immediate vicinity of such strong wind regions, there are zones with very low wind speeds and stagnating air masses. Here, the physical impulses for the city trees are small, but plant and animal pests can develop, which can also lead to damage to the tree substance and thus to the physical stability.

The often restricted root area reduce the possibilities for city trees to supply themselves with sufficient water and mechanical stability. A particular strength of ENVI_MET is the high-resolution simulation of vegetation as a living organism, which makes it possible to examine the vitality of trees or plants and to analyse possible interactions with buildings and the urban microclimate.

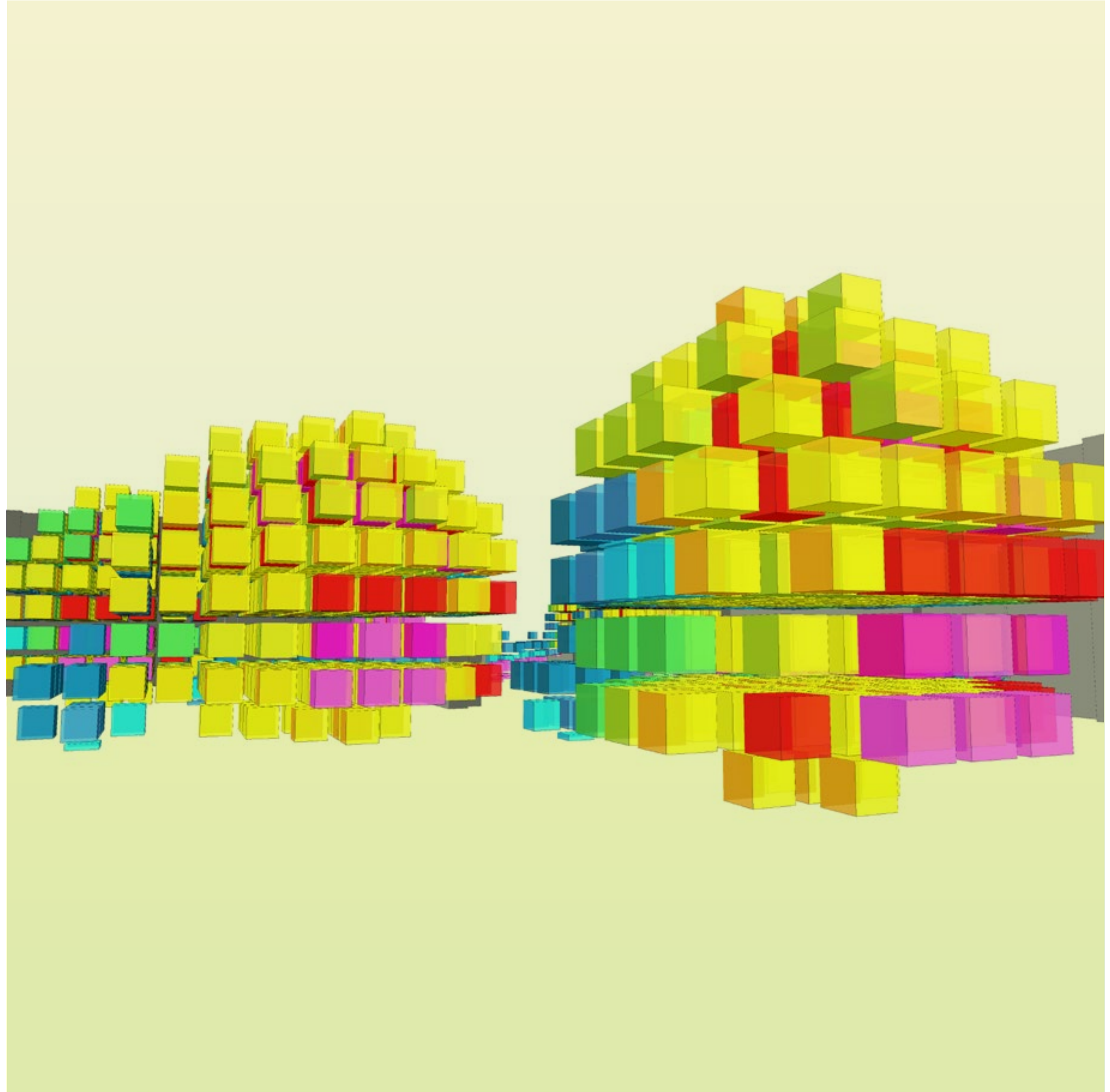


Wind conditions of trees close to a building

Urban vegetation is exposed to complex environmental conditions

The living conditions for vegetation in urban areas are complex and often hostile. Not only can the limited amount of soil and water cause severe stress, but also the wind and turbulence conditions especially in interaction with other urban objects such as buildings are complex. Buildings can produce wind sheltered zones in which the trees grow up with limited efforts to invest in their own stability. In contrast, the same species on the other side of the building might be exposed to increased turbulence, strong winds and rotating shear forces on their twigs and branches that lead to a very different shape of the tree. For a sustainable landscape architecture it is important to understand the specific conditions at the different locations, especially if changes in urban settings such as demolition or addition of buildings are planned.

ENVI_MET provides a detailed analysis of the environmental conditions with a focus on the demands of urban vegetation with respect to wind stress and storm risk.



Simulated leaf temperatures of two urban trees

Leaf temperatures are the key factor for urban cooling and tree health

One of the key benefits when addressing green solutions in urban climatology is the ability of vegetation to cool down the air temperature not only through shading, which is only effective during the day, but also through transpiration cooling. This process does not directly cool down the air but first cools down the leaves and then, through heat transfer, cools down the air flowing through the vegetation. So, the ability of vegetation to cool down the air requires a leaf temperature that is lower than the air temperature. Moreover, if the foliage temperature rises above a certain threshold, then the leaf tissue gets destroyed.

ENVI_MET calculates the leaf temperatures individually for each model grid box taking into account the photosynthesis rate, water availability and the local microclimate conditions.

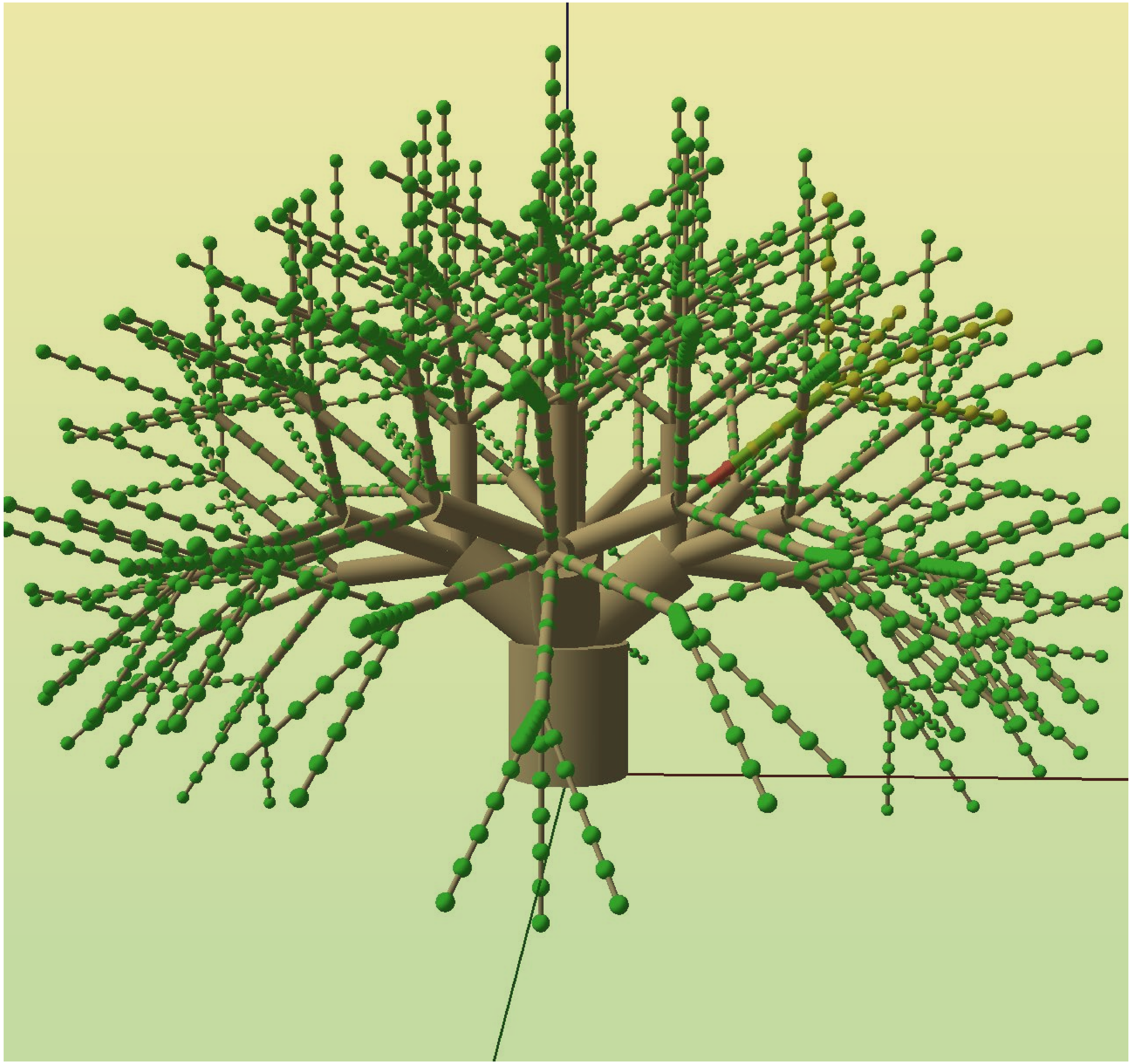
ENVI_MET Tree Pass

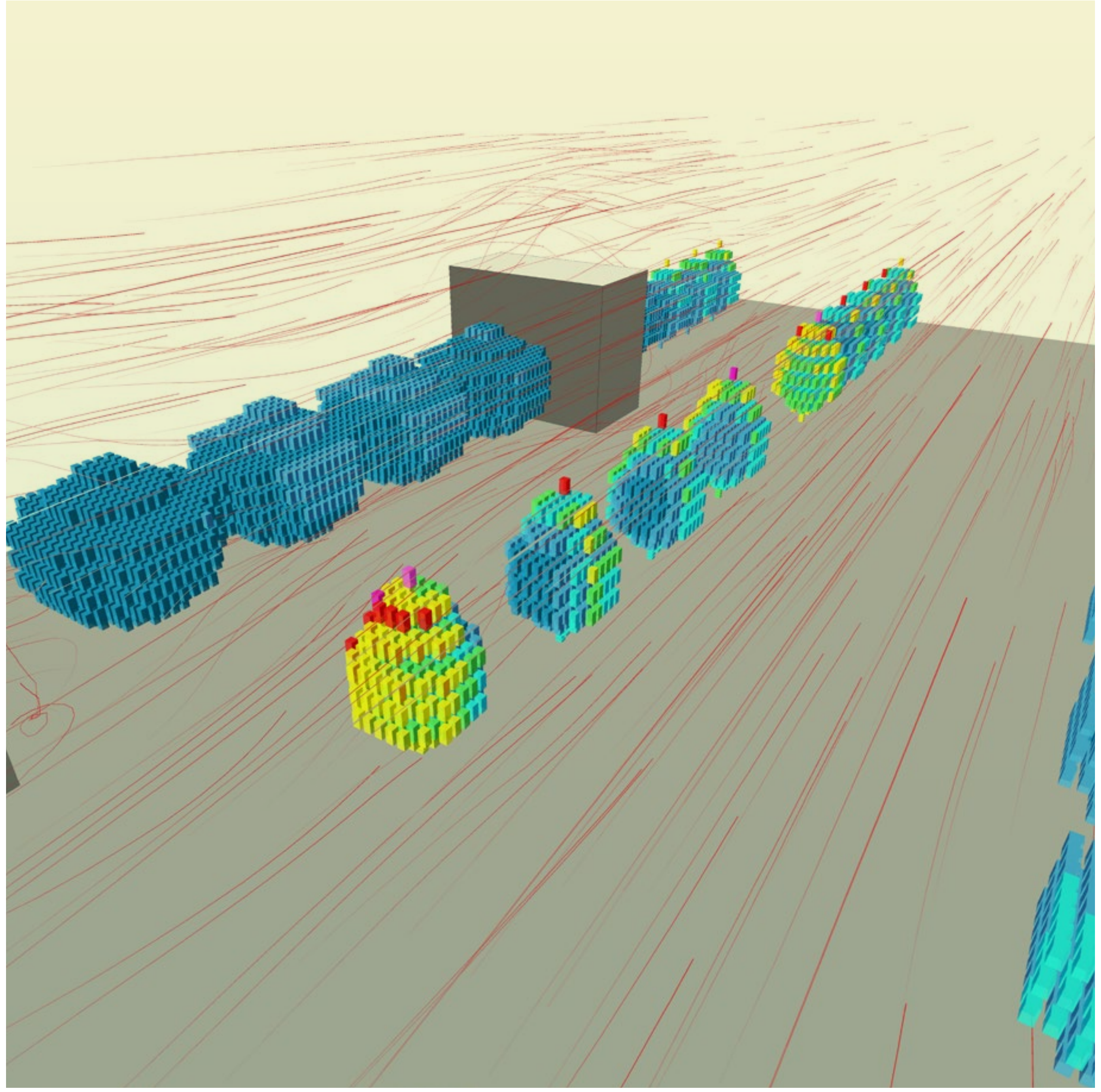
Finding the optimal growing conditions for selected plants or supporting landscape architects in finding the optimal planting scheme: The ENVI_MET Tree Pass is a comprehensive summary of all relevant microclimate growing conditions.

In the context of the ENVI_MET_Tree Pass method, plants or trees take on a central importance. For example, wind loads, water consumption and growing conditions at different sites can be investigated and compared to the plants' needs. The analysis of (potential) tree sites with regard to the local wind conditions in relation to the tree size and geometry is an important instrument for adapted landscape planning as well as preventive disaster protection.

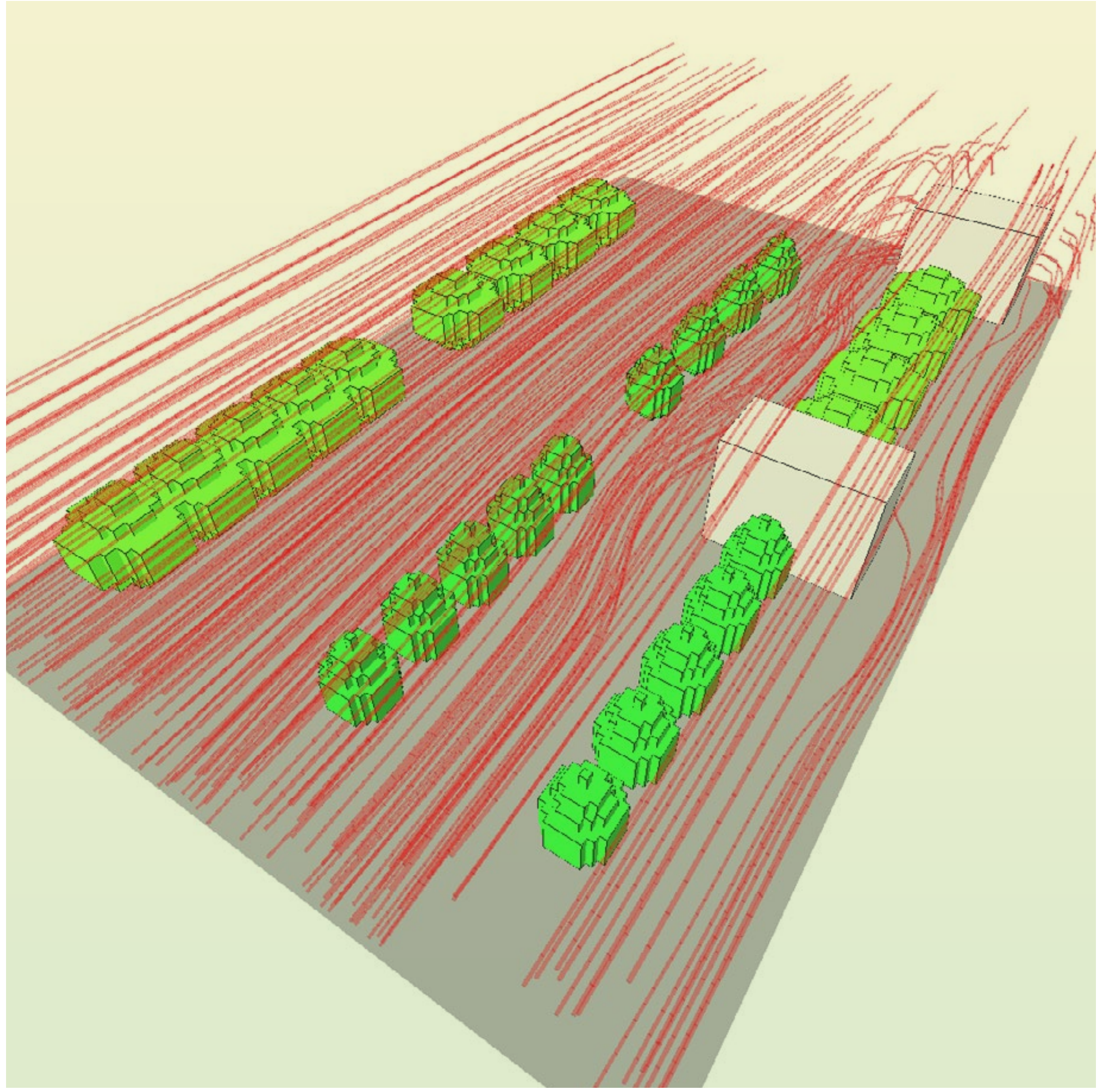
The high-resolution microclimate model represents the tree crown in general as a three-dimensional point cloud of different leaf surface densities connected to a stem skeleton. This approach allows a first quantitative assessment of the hazard potential caused by wind loads depending on tree geometry, location and meteorological situation. In addition to the purely physical forces that affect the tree's stability during strong wind events, the longer-term conditions of the site are of great importance. If strong wind events are accompanied with unusual wind directions, trees that are normally wind protected and therefore untrained may be more susceptible to damage.

The simulation can also be used to extend the risk assessment for trees to other relevant aspects such as pest infestation, thermal stress and water stress. The latter aspect is already used today in simulations for climate adaptation of cities.





Wind drag forces affecting urban trees



Wind streamlines in and between rows of different tree types

Wind risk and urban trees

Sustainable urban planning means not only providing a sustainable building infrastructure, but also to provide adequate growing and living conditions for the planned or existing trees.

In case of strong or unusual wind situations, urban trees can break and cause not only the loss of the green infrastructure, but also damage other urban elements or even injure the public.
The ENVI_MET Tree Pass analysis includes details of the wind and turbulence conditions at the location of the tree analysed. In addition, the mechanical forces that result from the wind loads on the different levels of the tree are calculated to identify possible points of damage and give advice on the best shaping of the trees.

Rows of trees act like a single object rather than a collection of individual trees

In both forests and urban environments trees are often organised in groups and rows. In this constellation, the arrangement of trees acts like a single object in terms of wind conditions or light access. Like humans, trees are trained during the growing process to adapt to their environmental conditions. Trees that are sheltered by other trees or by buildings therefore are often much less stable and have a more fragile geometry compared to those trees in the first rows that catch all the wind. The problem starts when single trees are removed or the wind field patterns change due to new buildings or removal of buildings. When suddenly the weaker trees are in the first row, they might not be able to withstand the new wind conditions. It is therefore important to analyse the environmental conditions in the whole picture to assess the impact of local changes.

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"Sustainabilty means construct
and live with the earth, not against it."

Daniela Bruse, CEO

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"Urban areas are highly complex systems with a multitude of interactions in space and time. To design resilient and sustainable cities, especially within the scope of future climate change, you need to know how changes in this system will influence urban wind patterns, local climate and air quality."

Michael Bruse, Prof. Dr., CDO