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Bridging the Implementation Gap: A Holistic Approach to Urban Climate Governance

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Abstract

As urbanization continues to grow, urban climate issues such as urban heat island effect have emerged. The "implementation gap" refers to the significant difference between the number of effective methods available to tackle these problems and the few cities where they have been implemented to some extent. Contrary to most literature, our hypothesis is that this gap is due to the research not being structured in a way that enables effective decision-making. Therefore, we propose an expanded concept of urban climate maps that includes all scales of the city and stages of urban development as a solution. Four case studies at different scales are briefly analyzed to reinforce this point and provide a clearer idea of the immense opportunity for cities to develop these climate maps.

Keywords

Urban Heat Island, Climate Maps, Urban Governance, Urban Planning, Shanghai

1. Introduction

1.1. Background

The urban heat island effect is a phenomenon in which cities experience higher temperatures than surrounding rural areas due to the absorption and retention of heat by built surfaces, such as buildings and roads. This can lead to a range of consequences, including:

1) Increased energy demand: Higher temperatures in cities can lead to increased energy demand for air conditioning and other cooling measures. Santamouris et al. (2015) estimated an average cooling penalty in urban versus rural buildings of 13.1%, a peak electricity penalty per degree of temperature rise of 0.45% up to 4.6% and an electricity penalty per degree of temperature rise and

per person of 21 (±10.4) W/˚C/person.

2) Decreased air quality: Higher temperatures can exacerbate air pollution and increase the concentration of harmful pollutants such as ozone and particulate matter. He et al. (2021) provide a literature review of research on the relationship between the urban heat island effect and urban pollution in cities over the past three decades. The review identifies a range of factors that contribute to the link between urban heat and pollution, including the impacts of hot temperatures on atmospheric chemistry and the behavior of pollutants in urban environments.

3) Decreased street comfort: Higher temperatures, reduced air circulation and high heat radiation can make it more challenging for people to spend time outside in urban areas. Qaid et al. (2016), for example, focus on the urban heat island phenomenon and its impact on outdoor thermal comfort at a micro-scale level in Putrajaya, Malaysia. The study emphasizes that the urban heat island effect cannot be generalized across different areas and stresses the need for a micro-level analysis to address the issue of human comfort.

There is a broad consensus that the urban heat island is a prime product of urban development (Levermore, 2018), particularly related to the modification of land cover/use, urban structure and building configurations (Makar et al., 2006; Fan & Sailor, 2005). Therefore, confronting the UHI demands long-term and fundamental changes in urban development.

Countless measures have been evaluated so far to address this issue with positive results. These include building geometry, urban density, built-up ratio (Rajagopalan et al., 2014; Kleerekoper et al., 2012; Gago et al., 2013; Razzaghmanesh et al., 2016), roughness length, canyons aspect ratio and sky view factor (Rizwan et al., 2008; Lee & Baik, 2010; Unger, 2004), vegetation or green spaces (Razzaghmanesh et al., 2016; Wang & Akbari, 2016), water bodies, cool sinks, pavements and open spaces (such as parking lots) (Luo & Asproudi, 2015), surface characteristics and building materials (Gago et al., 2013; Unger, 2004; Bonamente et al., 2013), usage of buildings or spaces (such as commercial, residential, office, etc.) and transportation (Li et al., 2013; Hsieh & Huang, 2016).

The effectiveness of most UHI mitigation measures have been widely evaluated in field measurements, numerical simulations, and remote sensing studies globally, showing strong dependence on site characteristics and background climate conditions (Bowler et al., 2010; Santamouris et al., 2017).

While there is a lack of economic evaluations on the effectiveness of mitigation measures against the urban heat island effect, a few studies have demonstrated the significant advantages of investing in such measures. Mekala et al. (2015) discuss the economic benefits implementing green infrastructure and estimate that potential public benefits of avoided health costs of about AU$75,049 per annum and potential private benefits of AU$3.9 million.

In their study, Whiteoak and Saigar (2019) offer an economic framework for estimating the benefits of greening and water management projects. They use a standard cost-benefit analysis approach to compare the costs of these projects with their potential benefits, such as water savings, health benefits, recreation value, and electricity savings. Through various scenarios, they conclude that while the heat mitigation achieved from greening projects may be modest, it is still significant, and there are several quantifiable economic benefits associated with such mitigation measures.

1.2. The Implementation Gap

While there is a consensus on the urgent need to address issues such as the urban heat island effect, and agreed-upon measures to mitigate it, numerous studies indicate that very few cities have taken concrete actions to address this problem (Hebbert, 2014). In this section, we will provide a summary of literature that examines the reasons for this disparity, which is commonly referred to as the "implementation gap". Numerous studies suggest that the dynamics of public entities, particularly their relationships with other stakeholders, play a significant role in the implementation gap.

Birkmann et al. (2010), for example, discuss the concept of adaptive urban governance in the context of climate change adaptation strategies. The authors argue that traditional governance structures are not sufficient to address the complex and dynamic challenges posed by climate change. They propose a new framework for adaptive urban governance that emphasizes collaboration, flexibility, and a systems-based approach. The article highlights the importance of stakeholder engagement, data-driven decision-making, and ongoing evaluation and adjustment of adaptation strategies. The authors conclude that adaptive urban governance is essential for effective climate change adaptation in cities and recommend further research to refine and implement this framework.

Given the history of their interaction, it is understandable to have concerns about the relationship between governments and urban planners. Over the past century, the inadequate collaboration between these entities has led to significant frustration, particularly in areas such as housing and mobility. Adelle and Russel examine previous attempts at policy integration, such as sustainable development and environ-mental policy integration, and identifies factors that have hindered their success, such as conflicting policy objectives, lack of political will, and insufficient resources and propose a set of principles for effective climate policy integration, including clear and measurable targets, coordinated policy frameworks, and stakeholder engagement.

Other articles suggest that the public may also have shortcomings contributing to the implementation gap. Wang et al. (2021) discuss the results of a survey conducted to understand public perceptions of urban heat island mitigation strategies and implementation strategies. The study found that respondents were supportive of urban heat island mitigation, with trees and green spaces being the most favored strategies. However, there were significant gaps in knowledge and implementation, with many respondents unaware of specific strategies and unsure of who is responsible for implementation. The article suggests that increasing public education and engagement is crucial for successful implementation of urban heat island mitigation strategies.

According to Parsaee et al. (2018) this issue is attributable to the fact that the paradigm of urban climate management systems considers the physical and engineering aspects of the urban warming phenomenon, and it neglects the socioeconomic, managerial, and climatic contexts and capacities of the city. Hence, the countermeasures against climatic issues (the urban heat island phenomenon) have thus far been offered but with a negligible consideration of feasibility in the urban development plans. One particularly interesting finding of this paper is the diagnosis that a general platform, as opposed to specific implementation studies, is crucial for facilitating co-operation among different stakeholders.

Runhaar et al. (2018), take this idea one step further by suggesting that not only is a platform that incorporates different factors necessary, but also one that is shared by cities globally to maximize synergies. The article is primarily focused on the mainstreaming of climate adaptation into policies and practices worldwide. They claim that qualitative assessment of outputs and outcomes suggests that effective outputs were reported when several mainstreaming strategies were employed simultaneously and when higher-level changes were operationalized at local level.

Degirmenci et al. (2021), provide the latest literature review that examines policy and technology responses to mitigate urban heat islands. The authors highlight the need for more research to better understand the effectiveness of different policy and technology solutions, as well as the need for interdisciplinary approaches that consider both technological and social factors. They also emphasize the importance of stakeholder engagement and public participation in the development and implementation of urban heat island mitigation strategies. Three key areas identified by them for evidence-based policymaking that are most relevant to our research are timescale analysis, effective policymaking instruments, and decision support and scenario planning.

In conclusion, according to most literature, the implementation gap is attributed to shortcomings beyond technical and academic factors, namely the government and the public. Recommended solutions often involve delivering existing knowledge to these stakeholders or fundamentally changing their motivations, functioning, and responsibilities to enable the implementation of necessary measures.

Only a few studies, mentioned in the previous section, attribute the implementation gap to technical reasons such as timescale analysis, mainstreaming, and articulation with social research.

1.3. Research Limitations

In contrast to prevailing research, we contend that closing the implementation gap is something to be achieved within the technical scope. Specifically, we believe that the lack of studies that address the two dimensions of time and scale is the most significant shortcoming in this area.

When considering the scope of urban governance, it becomes clear that it spans a broad range of time and scale, from the initial planning phase to post-assessment, and from individual buildings to entire regions.

Despite this wide-ranging scope, our review of the technical literature reveals a significant gap in research that comprehensively covers all aspects of urban governance. This is demonstrated in **Table 1** by categorizing previous research along according to their scope of time and scale, revealing a lack of studies that adequately address the full range of issues in urban governance. We consider here research collected by Parsaee et al. (2019).

The results are conclusive in terms of the lack of studies that address the problem in its entirety. This suggests that a more comprehensive approach to

Table 1. Classification of studies according to scale (B: building, N: neighborhood, C: city) and stage.

Article	Location	Scale	Stage			
			Pre-planning	Scheme-design	Evaluation	Post-Eval.
Kandya & Mohan, 2018	Delhi, India	B	x			
Touchaei et al., 2016	Montreal, Canada	B		x		
Yang et al., 2018	Singapore	B	x			
Wang et al., 2016	Montreal, Canada	N	x			
Santamouris et al., 2018	Sydney, Australia	N	x	x		
Morakinyo et al., 2018	Hong Kong	N	x	x		
Taleghani et al., 2019	Los Angeles, USA	N	x	x		
Coccolo et al., 2018	Dubai, UAE	N	x			
Lee & Mayer, 2018	Stuttgart, Germany	B, N	x	x		
Müller et al., 2014	Oberhausen, Germany	N	x			
Zhao et al., 2018	Tempe, AZ, USA	N		x		
Zhang et al, 2018	Wuhan, China	N	x			
Lontorfos et al., 2018	Athens, Greece	C			x	x
Kyriakodis & Santamouris, 2018	Athens, Greece	C			x	x
Sharma et al., 2016	Chicago, USA	C	x			
Hsieh & Huang, 2016	Tainan City, Taiwan region	C	x	x		
Norton et al., 2015	Melbourne, Australia	C	x			
Tan et al., 2016	Hong Kong	C		x		
Gilbert et al., 2016	California, USA	B, C			x	
Vahmani et al., 2016	California, USA	C	x			
Villanueva-Solis, 2017	Mexicali, México	B, C	x			

urban governance research and policy development is needed to address the challenges of urbanization in a rapidly changing world. By focusing on both the time and scale dimensions of the issue and drawing on a wide range of expertise and perspectives, we can develop more effective and sustainable solutions to the complex challenges of urban governance.

After an extensive review of the existing literature, a significant gap in research has become evident in the realm of public policies that encompass various scales and planning stages. While this paper does not aim to present a comprehensive framework to address this gap, our objective is to offer a comprehensive perspective through a re-view of case studies spanning different scales and stages. The purpose is to underscore the potential advantages of adopting a holistic approach to this issue, one that incorporates the collaborative efforts of planners in a comprehensive manner.

It is important to note that each of the case studies featured in this paper may not introduce radical innovations on its own. Instead, their role within this work is to serve as illustrative examples, shedding light on the diverse challenges and contributions that come with decision-making processes at different stages and scales. Additionally, they collectively point towards the blueprint for a more extensive platform designed to tackle this issue in a broader context.

2. Materials and Methods

In our research, we placed emphasis on wind management as a priority over other aspects of climate management, following the findings of Zhang et al. (2020) who re-viewed numerous studies on urban climate. Their review concluded that building height difference and time-varying inflow conditions are the most significant factors, while tree planting, vehicle-induced turbulence, thermal and/or wall heat conditions have weak influence. Based on their findings, they proposed several guidelines regarding building height and shape that they deemed most effective for managing the urban climate.

Recent advances in two key technologies have enabled the development of the holistic model with emphasis in wind management that we propose: urban reconstruction and wind simulation.

Urban reconstruction involves creating digital representations of cities using various techniques, including photogrammetry, LiDAR, and laser scanning. The accuracy of these models has significantly improved in the past decade, enabling the capture of critical details necessary for accurate climate simulation, such as buildings and vegetation. Wang et al. (2018) have reviewed different methods and outcomes for city modeling from LIDAR point clouds and concluded that despite challenges, the latest research indicates the effectiveness of this technology in modeling cities at different scales and levels of detail.

The second key technology is wind simulation. Numerous studies have been conducted to develop and test different models for simulating wind patterns in urban environments, using a range of techniques such as computational fluid dynamics (CFD), wind tunnel experiments, and empirical models. Toparlar et al. (2017) review 183 applications of computational fluid dynamics (CFD) in analyzing the urban microclimate. Some aspects to highlight are:

- Increasing popularity: the number of studies in the field in the last three years exceeds that of the thirty precedent years.
- The historical review suggests a shift in the trend of CFD microclimate studies from model development to case studies and urban scale adaptation measures and highlights the potential for CFD to transfer urban climate knowledge into engineering and design practice.
- Different targets: temperature related, thermal comfort related, heat transfer related, flow/ventilation related, humidity/mass transfer related, air quality, etc. They conclude that "Future studies might focus more on systematic studies with multiple scales (e.g. mesoscale, building scale) and aspects (e.g. economical) to transfer the gained knowledge from urban climatology to routine building and urban design guidelines."

Proposals for a platform like the one we are suggesting are not new, and the concept of urban climate maps has been around since the 1980s when Knoch developed the term. Although our platform intends to cover a broader spectrum than what was suggested in Knoch's work, we will use the term "urban climate maps" or "urban climate atlas" to refer to our proposed platform. For further information on the development of urban climate maps, we recommend Ren & Katzschner review article (Ren et al., 2011).

Urban climate information atlas is an information assessment tool for urban climate factors and urban planning related factors, which presents urban climate phenomena and related issues on a two-dimensional spatial map, realizes the visualization of climate information, solves the problem that urban climate information is difficult to be read and used, enables planners and designers to easily obtain urban climate in-formation through the atlas, and combine it with the current situation of urban land use to make a correct assessment and ultimately guide urban design and planning practice.

The urban climate information maps rely on objective urban meteorological data (temperature, precipitation, wind, solar radiation, etc.), information related to urban land use, site topography, site vegetation and greenery (see **Table 2**), and analyze three main aspects about urban climate.

Urban heat island maps consist of three essential components. The first element is the contextual meteorological variables, which refers to the larger meteorological context surrounding the city. The second element encompasses the physical characteristics of the city, including its geography and physical form, such as buildings, vegetation, and materials. Lastly, the maps consider the target meteorological conditions that researchers want to investigate or modify, such as the urban heat island effect, human comfort levels, or meteorological conditions of a particular location.

Of course, the specific variables to be analyzed will depend on the unique

Table 2. Classification of data needed to create a climate atlas (created by the authors).

Categories	Map Categories		Data Classification	Purpose and Contents
Contextual meteorological variables	Meteorological map	Temperature distribution	Temperature (season - time)	Define the scope of heat island distribution
			Long-term average temperature change	
		Airflow distribution	Wind speed (season - time)	Clarify the characteristics of airflow distribution, the Monsoon, prevailing wind distribution range
			Wind direction (season - time)	
		Sunshine Distribution	Sunshine intensity (season - time)	Define the distribution of solar radiation
			Sunshine duration (season - time)	
Physical characteristics	Terrain		Elevation	Understanding of topographic features (basin climate and mountain valley wind possibilities)
			Water surface distribution	Understanding water distribution
	Land Use		Land Use Distribution	Understanding the correlation between surface temperature, land use and land cover status; understanding the characteristics of air currents
			Vegetation Distribution	
			Building Distribution	
			Road Distribution	
			Greening Distribution	
Target meteorological conditions	Atmospheric pollution concentration distribution		NO$_X$ (season - time)	Understanding the status of air pollution
			SPM (season - time)	
	Distribution of pollution sources		Traffic volume (weekdays/rest days, day/night)	Understand the factors affecting air pollution and heat emissions
			Pollution emission facilities (annual average volume)	
	Heat emission distribution		Apparent heat emissions (annual average)	Understanding the characteristics of regional heat emissions
			Potential heat emissions	
	Surface temperature distribution		Ground surface temperature (day/night, season)	Understanding the impact of anthropogenic heat sources on the regional environment
	Distribution of somatosensory indicators		Somatosensory indicators (SET)	Understanding the effect of ambient temperature on human comfort

challenges and characteristics of each city. For instance, the variables that are important for a tropical city may differ from those that are essential for a colder region, even though the approach to the analysis remains the same.

Combining the spatial and temporal scales in meteorology and the scale of urban planning, the simulation and assessment of urban climate environment can be divided into four scales: "city-region-neighborhood-buildings", with different focuses on planning contents and applications (**Table 3**). The city level focuses on monitoring and protecting the urban climate environment, identifying key areas such as urban heat island cores and urban wind corridors in conjunction with urban climate strategies, and forming general planning recommendations. Climate simulation at the regional level can be used to clarify the characteristics of the regional urban climate environment, improve the outdoor comfort of regional public spaces, and provide guidelines for urban design in conjunction with regional planning. Climate simulation at the neighborhood level can clarify the characteristics of the climate environment of streets and building clusters, identify the weak areas of the neighborhood climate environment, and is mostly used for the assessment of the built-up area environment such as urban renewal. Climate simulation at the building unit level can be used to evaluate design solutions and identify climate problems in built-up areas and propose strategies, focusing on local thermal and wind environments. The modeling requirements include detailed information on building entities, vegetation, water bodies, substrate materials, etc., and need to be combined with field measurement data, aiming to improve out-door comfort of buildings and optimize energy-saving building design.

The climate simulation and evaluation program for urban built-up areas adopts the operation path of "data collection-simulation processing-program evaluation—on-site survey comparison", as summarized in **Figure 1**. Data collection includes meteorological data and physical data of built-up environment. With the help of climate simulation software, the local thermal, wind, sound and

Table 3. Climate planning content and applications at multiple scales (created by the authors).

Planning Scale	Planning and design level	Planning and design content	Planning and design applications	Climate scale
City Scale	1. Strategic planning for spatial development 2. Urban master plan	Spatial distribution of urban clusters and municipalities at all levels, industrial spatial distribution planning, population growth control, land use scale, etc.	Define the characteristics of the urban climatic environment and protect and build urban windways	Macro 50 - 100 km
Regional Scale	1. Zoning plan 2. Detailed control plan 3. Urban design	Spatial planning of urban districts, spatial distribution of land classification, control of urban form such as green space and natural vegetation, etc.	Define the characteristics of the regional climatic environment, such as determine the wind compensation, the role of space	Midview 1 - 50 km
Neighborhood Scale	1. Detailed construction planning 2. Urban Street design	Urban form control, building height and street width, building orientation control, green space and leisure land distribution, etc.	Define the characteristics of the climatic environment of streets and building groups to improve the outdoor comfort of neighborhoods	Micro 10 - 1000 m
Building Scale	1. Architectural design scheme	Single building form, orientation control and surrounding open space control	Enhance outdoor comfort of buildings and optimize energy-saving building design	Micro 0 - 100 m

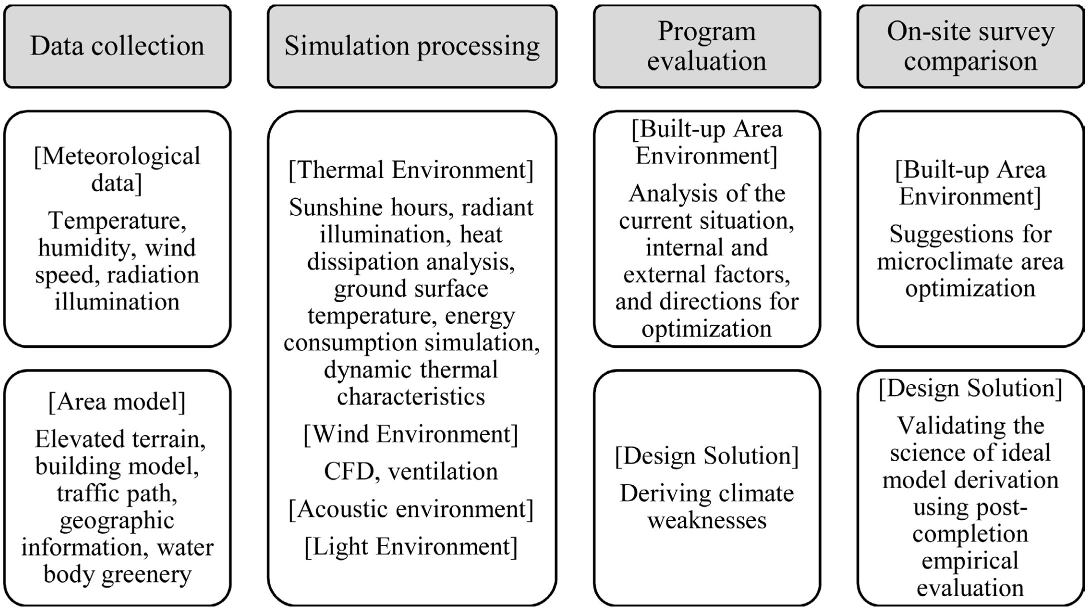


Figure 1. Climate simulation and evaluation operations path (created by the authors).

light environments are simulated, and the factors causing the unfavorable points are identified and analyzed together with the spatial pattern of the scheme and the surrounding environment, and the accuracy of the evaluation results is verified through on-site measurements, and finally, targeted recommendations are made for the tested area.

At the same time, climate simulation and assessment of urban built-up areas can be carried out throughout the whole process of urban planning and architectural de-sign: pre-planning, scheme design, evaluation and optimization, and post-evaluation, which can clarify the design conditions, propose design strategies, optimize the design scheme, and improve the built-up environment, specifically including the following processes.

- Pre-planning: The analysis of the pre-planning relies on urban climate maps, meteorological data, etc., to clarify the climate design conditions from the site's location conditions and internal environment, and to propose corresponding climate design suggestions. This process is mainly conducted by government departments and program planners.
- Scheme design: according to the site surrounding climate environment, modeling of the site and its surroundings, exploring the distribution of the current wind and thermal environment of the site with the help of climate simulation software, identifying the unfavorable points, and further proposing design strategies in spatial form, building skin, greenery and water bodies, urban substrate, etc. The process is applied to the design of building monoliths or urban renewal projects, which are implemented by design units.
- Evaluation and optimization: The analysis of the design plan is focused on the future prediction, from the plan itself, to find out the climate weaknesses to be corrected, to assist the plan to build a better climate environment. In

addition, the design solution needs to get the feedback from the actual measurement after the completion, to confirm the scientificity and validity of the ideal model deduction and form a closed loop of path optimization.

- Post-assessment: The post-assessment focuses on the analysis of the current situation, from the external influencing factors, using scientific simulation to explore the impact of the surrounding urban morphology changes on the regional climate environment; from the internal influencing factors, more with the actual measurement experiments to analyze the regional environment, and extrapolate to the spatial morphology of each microclimate point, green bodies of water, substratum materials and other detailed control elements.

3. Results

We developed four cases at different scales in the city of Shanghai, aiming to demonstrate how each case contributes to the overall solution of the problem. It is important to note that this analysis is not an example of the platform we are proposing. Instead, its objective is to provide evidence of the importance of developing such a platform.

3.1. City Scale: Evaluation of Ventilation Potential in Shanghai

Urban climate maps can be used to simulate and evaluate the climate environment at an urban scale, identifying weak areas such as urban heat islands, static wind zones, pollution hotspots, etc. This information can then be used to develop urban design guidelines and best practices to guide urban planning and design.

The wind in cities is influenced by numerous factors such as subsurface morphology, building density, height, water systems, and green space coverage. In a simulation study of the ventilation potential of Shanghai's downtown area, we evaluated four indicators: building density, height, water coverage, and green space coverage, with the help of meteorological station observation data and vector map data combined with subsurface conditions.

The study revealed that the ventilation potential of Shanghai's central city is better than the west, with the periphery being better than the center. The Pudong area showed the best ventilation potential, especially the southeast side with more undeveloped land and more farmland, green land, water systems, low-rise factories, and multistorey residential buildings.

The ventilation potential is low in the Puxi area, especially in and around the "V" shaped area on the opposite bank of Lujiazui. The high-density, high-rise, and super high-rise buildings in the area, coupled with a lack of large green areas and water systems, lead to poor ventilation potential. These areas experience low wind speeds all year round, with the Xuhui weather station recording a significant decrease in wind speed year after year, as demonstrated in **Figure 2**.

The study of the ventilation potential (**Figure 3**) of the downtown area of Shanghai provides guidance for subsequent development in Shanghai. For new development projects, relevant development indicators must be strictly

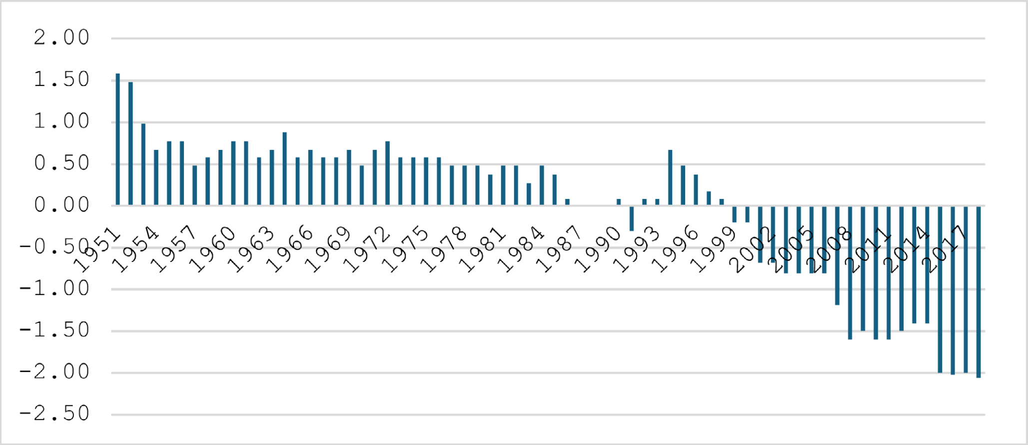


Figure 2. Wind speed deviation over average wind speed deviation by Xuhui weather station.

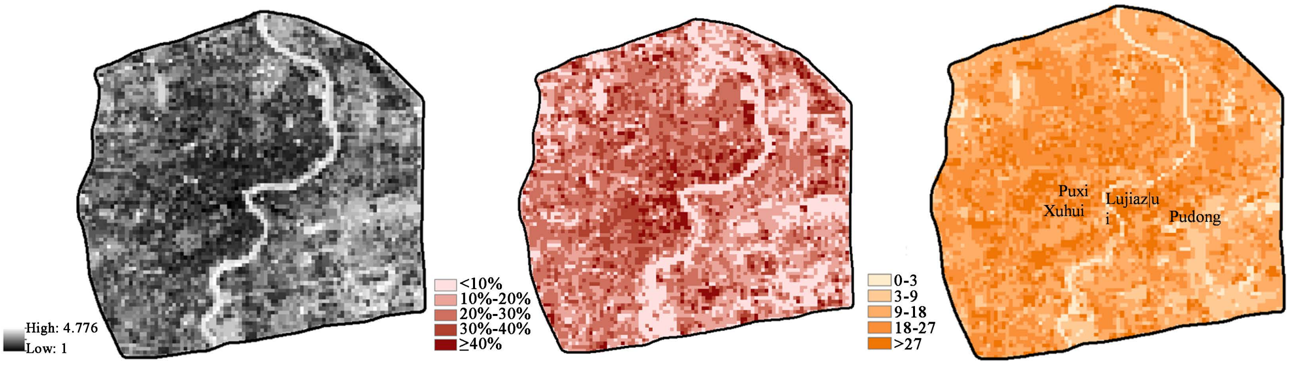


Figure 3. Ventilation potential of down Shanghai (2-a), and its influencing factors such as subsurface morphology represented by building density (2-b), height (2-c), water systems (2-d), and green space coverage (2-e).

controlled, and wind environment measurement should be introduced as a link to prevent damage to the regional wind environment. For old city transformation and urban renewal areas, opportunities of demolition and transformation should be seized to prioritize planning and design solutions that improve the urban wind environment. Ultimately, optimizing the urban wind environment and protecting the urban ecological environment can be achieved.

This case study serves as an example of the relevant data and actions needed to assess urban conditions on a larger scale. By conducting such an assessment, policymakers can determine the areas and approaches that require attention for both developed and expanding urban areas. Although our case study only provides an initial diagnosis of the city, a comprehensive model covering all planning stages could, for example, calculate the overall climate impact of developing a specific area on the entire city.

3.2. Region Scale: Evaluation of the Wind Environment along the Yangpu Riverfront in Shanghai

The simulation and assessment of the regional-scale climate environment aim to identify potential weak points, vulnerable materials and details, and analyze them from a planning perspective. Urban design techniques such as urban layout and building form can then be used to optimize and improve these weak points, providing new perspectives and pathways for the optimization of the urban climate environment.

A case study of the wind environment at the Yangpu Riverfront was conducted, focusing on a 2 km * 3 km high-density area containing a headquarters office and cultural and creative community in the middle section of the project. Most relevant results are shown in **Figure 4**.

The study found that during summer, the wind speed inside the plot is low in the middle part of Yangpu Riverfront, which is not conducive to evapotranspiration. In winter, the wind speed at the southeast entrance is high, which is not conducive to thermal comfort. Additionally, the compact layout on the west side of the site may not be conducive to the dissipation of harmful gases due to increasing traffic and exhaust emissions. **Figure 5** showcases potential designs that take advantage of the previous diagnosis.

3.3. Neighborhood Scale: Climate Simulation Evaluation of Cao Yang First Village, Shanghai

Before initiating the planning and design of an urban renewal project, it is crucial to conduct a pre-assessment to analyze the microclimate and thermal comfort

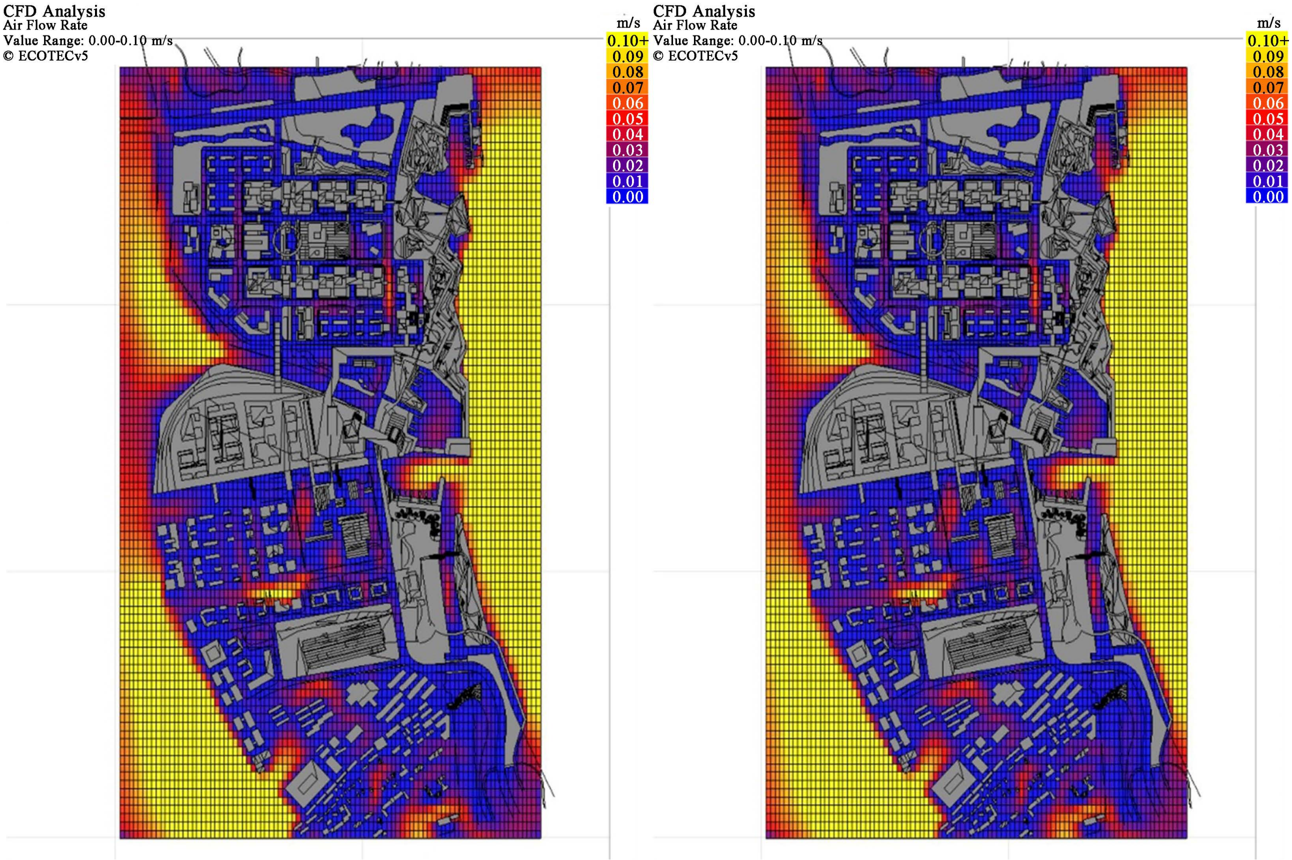


Figure 4. Wind speed of case site in summer (left) and winter (right), a simulation by WinAir, plugin unit of Ecotect, a CFD Software.

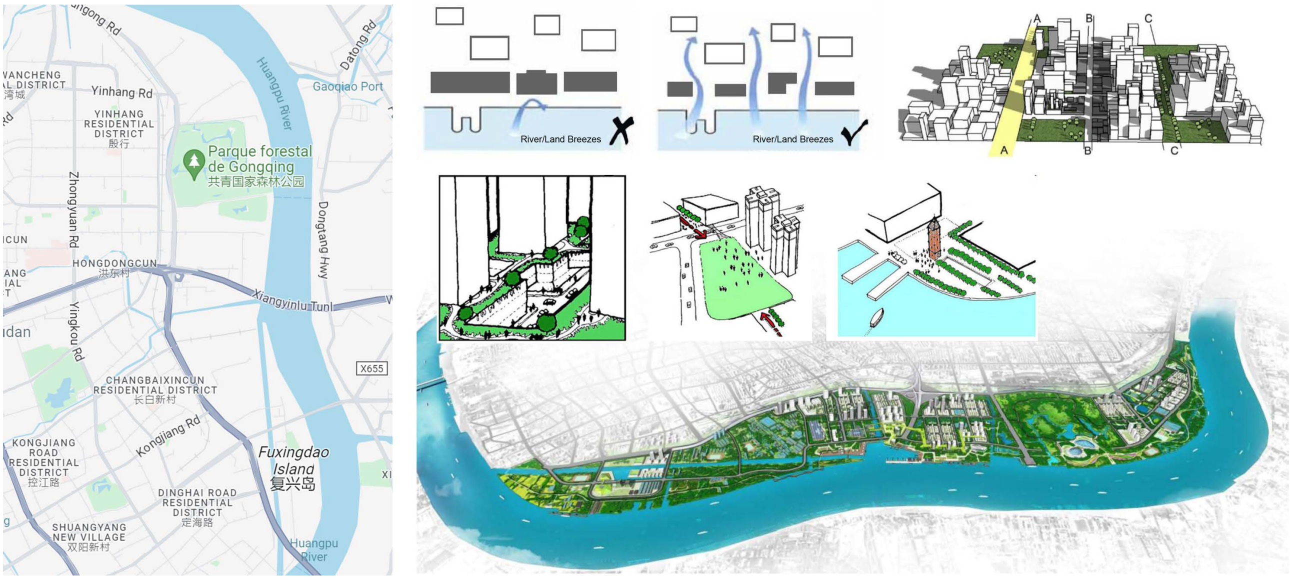


Figure 5. Overview of design solutions in the riverside block and location of the site.

conditions of the project. This pre-assessment can serve as a guide for planning and designing the project. Cao Yang Yicun, located in Putuo District, Shanghai, falls under the fourth category of historical protected buildings in Shanghai. In 2019, Putuo District launched a comprehensive restoration plan to renovate the old neighborhood, with one of its objectives being to improve the climatic conditions.

For this purpose, a climate environment simulation study of Cao Yang Yicun was conducted, by modeling the neighborhood characteristics such as buildings, vegetation, water bodies and pavement types, and conducting quantitative simulation and analysis with the help of Envimet software.

Simulation results are showcased in **Figure 6**. The streets of Cao Yang Yicun follow the dominant wind direction, but the row layout in the block is poorly oriented to the dominant wind direction, and most of the area is a low wind area or even no wind area. Moreover, the buildings in the block are low and widely spaced, and there are large open spaces, which makes the internal thermal comfort distribution poor. The street trees on both sides of the street are well distributed, so that the microclimate and thermal comfort at the street are well distributed. The better ecological conditions of the block improve the overall air temperature of the block and improve the microclimate and thermal comfort to a certain extent. However, the space within the block needs to be improved in a focused manner.

There are two types of unfavorable spaces in the neighborhood. One is the unfavorable point of wind speed where the blocking effect on wind is strong. One is the open space that is subject to a greater degree of solar radiation. Cao Yang First Village is mostly old houses with cultural value, so it is not advisable to change the buildings too much. Therefore, only some of the unfavorable wind speed points in the neighborhood are opened to improve the ventilation capacity of the neighborhood. In the improvement of the neighborhood space, the scale

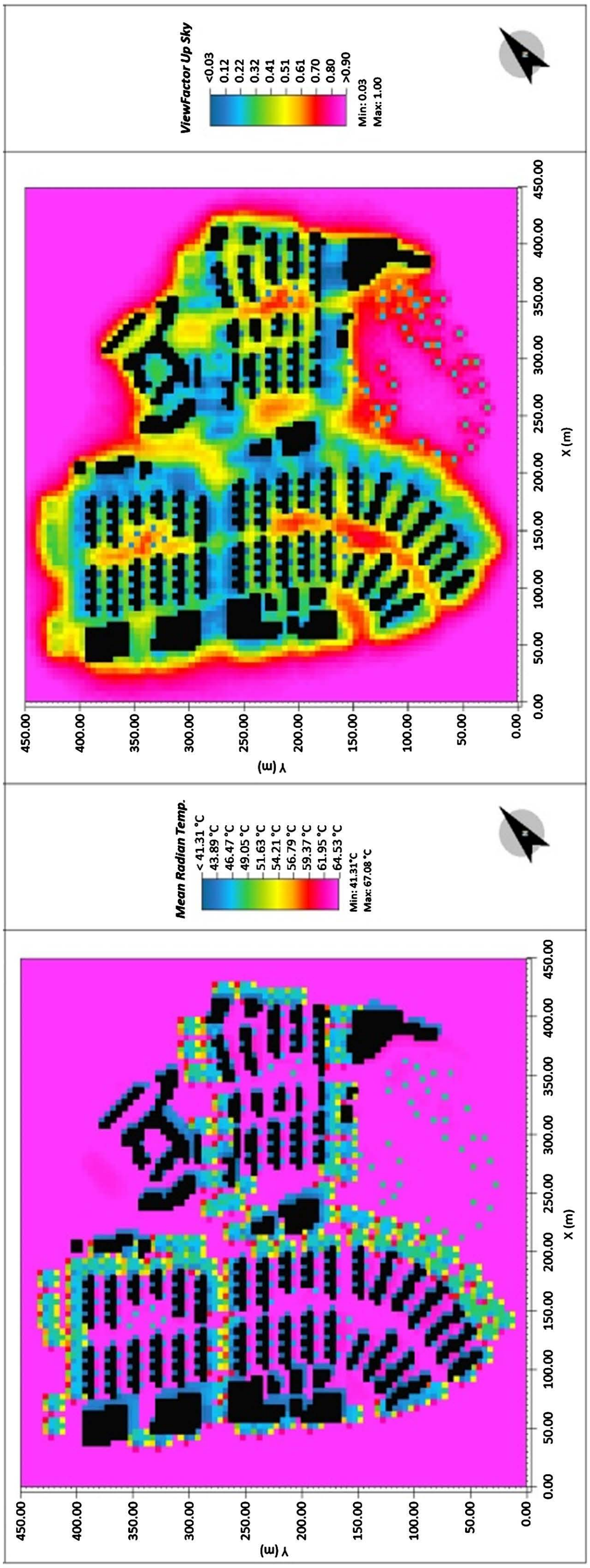


Figure 6. Mean radiation temperature (Left, 5-a) and Sky View Factor (Right, 5-b) for Caoyang Yi Cun Village, a simulation by ENVI-met software.

of open space should be reduced, and the shaded area of the neighborhood should be increased by arranging trees and grass to improve the open space in the status quo. In addition, the block pavement type should be improved appropriately. Therefore, the microclimate simulation analysis of Cao Yang Yicun can be used as a pre-analysis stage in the urban renewal process to provide a basis and strategic guidance for the subsequent urban renewal.

In conclusion, before starting any urban renewal project at the neighborhood scale, a pre-assessment to analyze the microclimate and thermal comfort conditions is crucial. This analysis can guide the planning and design of the project. The case of Cao Yang Yicun in Shanghai demonstrated that modeling the neighborhood characteristics and conducting quantitative simulation and analysis can identify the unfavorable spaces that need improvement, such as the areas with low wind speed or high solar radiation. Improving the ventilation capacity, reducing the open space, increasing the shaded area, and improving the pavement type are some of the strategies that can be implemented. The microclimate simulation analysis of a neighborhood can serve as a basis and strategic guidance for subsequent urban renewal projects.

3.4. Building Scale: Shanghai Xujiahui Center Area Simulation Evaluation

Including climate assessment in the evaluation of design options for new urban areas is an effective way to reduce negative impacts on the urban environment and improve outdoor comfort. In the study of climate environment simulation assessment of Xujiahui central area, a 1 km × 1 km test area containing Shanghai Jiaotong University Xujiahui campus, commercial land in Xujiahui business district, and surrounding residential land was selected (**Figure 7**). This area is in the center of the urban heat island and suffers from a local urban canyon effect and screen effect due to the existing planning layout. Furthermore, the heavy traffic flow around Xujiahui business district makes it difficult to dissipate the exhaust pollution from vehicles, leading to increasingly severe air pollution.

The test model analyzed four phases from 2002, 2009, 2017, and post-2017 to understand the evolution of the climate environment around the campus and the impact of the new Xujiahui Center on the climate environment.

The evolution of the site is summarized in **Figure 8**. To the southeast of the site is the Grand Gateway 66 Plaza, completed in 2006, and the Xujiahui shopping district, completed in 1998, which has several commercial and office buildings over two hundred meters in height. To the south of the site, the 370-meter-high Xujiahui Center will be built. The test model was selected to analyze four phases from 2002 - 2009 - 2017 - post-2017 to analyze the evolution of the climate environment around the campus, focusing on the impact of the new Xujiahui Center on the climate environment.

Comparing summer ventilation simulations between 2002 and 2017, it was found that the completion of the Gateway Plaza in 2009 had a negative and

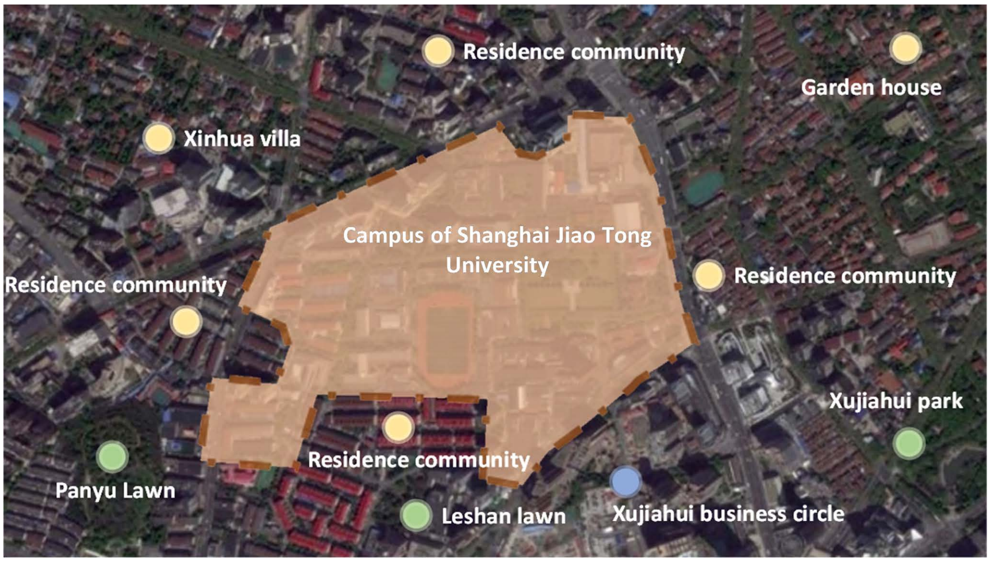


Figure 7. Xujiahui central area map and key spots.

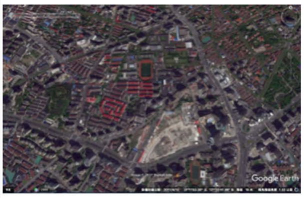
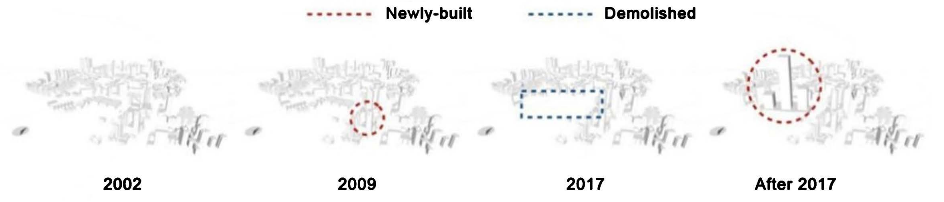
Time	2002-2009	2009-2017	2017-
Satellite imagery			
Model	 		
Detail	Xuhui campus of SJTU and Xujiahui business district was completed, Grand Gateway 66 was under construction in the southeast	Grand Gateway 66 was completed, and block 9C030201, C030202, C030203 of Xujiahui community was under demolition	The original Xujiahui community will be built into the Xujiahui center, with a floor area of 580,000 m^2 and a height limit of 370m

Figure 8. Construction and demolition information during 2012-2017.

significant impact on the wind environment on campus. Therefore, it is crucial to perform an ecological analysis of any new building to assess its impact on the local urban climate of the surrounding environment. Different design options can be compared and ranked to select the best one. For instance, building three high-rise buildings on the south side of the campus, with heights of 370, 180, and 160 meters, significantly improves wind speed on the campus according to simulation results. Additionally, Figure 9 shows that comparing the wind environment with 3D visual form provides more visual evidence for planners.

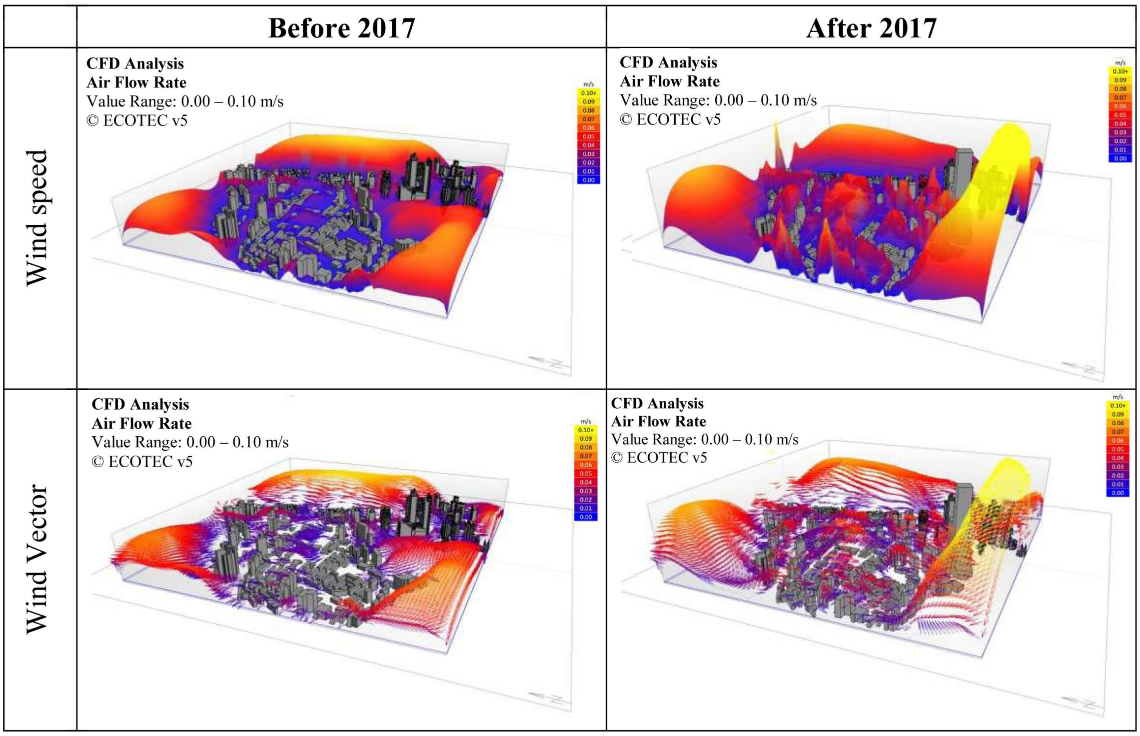


Figure 9. A visual comparison of the wind environment in summer (June-August) at 1.5 meters, a simulation by WinAir, plugin unit of Ecotect, a CFD Software.

4. Discussion and Conclusion

This study addresses the problem of the implementation gap in the urban climate spectrum, which refers to the disparity between the solutions available to solve weather-related problems and the scarce implementation of these solutions. Our hypothesis is that this is due to the lack of platforms (which we refer to as climate maps based on previous literature) that assist stakeholders in understanding the problem and making informed decisions.

Our analysis of the literature on this topic demonstrates how far we are from such a platform. There are no studies that analyze the problem comprehensively, specifically including the dimensions of time and scale. In Part 1, we defined some of the conceptual characteristics of the platform around these two dimensions, and in Part 2, we analyzed case studies at different scales.

Through the case studies, we attempted to demonstrate the complementarity of different scales in addressing the problem. In fact, only by considering the various scales can all necessary elements for improving the urban climate be brought into play:

- City scale: zoning, new development, wind corridors
- Regional scale: public spaces, wind corridors, water resources, greenery, and colors
- Neighborhood scale: building shape, color
- Building scale: shape, shading, color

It is important to note that this analysis does not exemplify the platform that we advocate for, but rather aims to provide supplementary proof of the importance of creating such a platform. However, there are limitations to our study:

- None of the case studies covered all stages.
- Although all case studies were in Shanghai, the relationship between each of them was not fully exploited.
- We focused on wind simulation. Although this decision is not arbitrary since literature shows it to be one of the most important variables, a comprehensive climate map should consider more variables.

Despite these limitations, we believe that the arguments presented in this paper are sufficient evidence for governments and other institutions to begin working immediately on constructing climate maps.

One last point worth emphasizing is that of mainstreaming (Runhaar et al., 2018), which we already discussed in the introduction. Our paper highlights the significant resources required to build climate maps comprehensive enough for effective decision-making. We believe that only by setting global guidelines and unifying the efforts of all cities under shared criteria can we effectively tackle urban climate problems.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Birkmann, J., Garschagen, M., Kraas, F., & Quang, N. (2010). Adaptive Urban Governance: New Challenges for the Second Generation of Urban Adaptation Strategies to Climate Change. *Sustainability Science, 5,* 185-206. https://doi.org/10.1007/s11625-010-0111-3

Bonamente, E., Rossi, F., Coccia, V., Pisello, A. L., Nicolini, A., Castellani, B., Santamouris, M. et al. (2013). An Energy-Balanced Analytic Model for Urban Heat Canyons: Comparison with Experimental Data. *Advances in Building Energy Research,* 7, 222-234. https://doi.org/10.1080/17512549.2013.865561

Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban Greening to Cool Towns and Cities: A Systematic Review of the Empirical Evidence. *Landscape and Urban Planning, 97,* 147-155. https://doi.org/10.1016/j.landurbplan.2010.05.006

Coccolo, S., Pearlmutter, D., & Kaempf, J. (2018). Thermal Comfort Maps to Estimate the Impact of Urban Greening on the Outdoor Human Comfort. *Urban Forestry & Urban Greening, 35,* 91-105. https://doi.org/10.1016/j.ufug.2018.08.007

Degirmenci, K., Desouza, K. C., Fieuw, W., Watson, R. T., & Yigitcanlar, T. (2021). Understanding Policy and Technology Responses in Mitigating Urban Heat Islands: A Literature Review and Directions for Future Research. *Sustainable Cities and Society, 70,* Article 102873. https://doi.org/10.1016/j.scs.2021.102873

Fan, H., & Sailor, D. J. (2005). Modeling the Impacts of Anthropogenic Heating on the Urban Climate of Philadelphia: A Comparison of Implementations in Two PBL Schemes. *Atmospheric Environment, 39,* 73-84. https://doi.org/10.1016/j.atmosenv.2004.09.031

Gago, E. J., Roldan, J., Pacheco-Torres, R., & Ordóñez, J. (2013). The City and Urban Heat Islands: A Review of Strategies to Mitigate Adverse Effects. *Renewable and Sustainable Energy Reviews, 25,* 749-758. https://doi.org/10.1016/j.rser.2013.05.057

Gilbert, H., Mandel, B. H., & Levinson, R. (2016). Keeping California Cool: Recent Cool Community Developments. *Energy and Buildings, 114,* 20-26. https://doi.org/10.1016/j.enbuild.2015.06.023

He, B. J., Wang, J., Liu, H., & Ulpiani, G. (2021). Localized Synergies Between Heat Waves and Urban Heat Islands: Implications on Human Thermal Comfort and Urban Heat Management. *Environmental Research, 193,* Article 110584. https://doi.org/10.1016/j.envres.2020.110584

Hebbert, M. (2014). Climatology for City Planning in Historical Perspective. *Urban Climate, 10,* 204-215. https://doi.org/10.1016/j.uclim.2014.07.001

Hsieh, C. M., & Huang, H. C. (2016). Mitigating Urban Heat Islands: A Method to Identify Potential Wind Corridor for Cooling and Ventilation. *Computers, Environment and Urban Systems, 57,* 130-143. https://doi.org/10.1016/j.compenvurbsys.2016.02.005

Kandya, A., & Mohan, M. (2018). Mitigating the Urban Heat Island Effect through Building Envelope Modifications. *Energy and Buildings, 164,* 266-277. https://doi.org/10.1016/j.enbuild.2018.01.014

Kleerekoper, L., Van Esch, M., & Salcedo, T. B. (2012). How to Make a City Climate-Proof, Addressing the Urban Heat Island Effect. *Resources, Conservation and Recycling, 64,* 30-38. https://doi.org/10.1016/j.resconrec.2011.06.004

Kyriakodis, G. E., & Santamouris, M. (2018). Using Reflective Pavements to Mitigate Urban Heat Island in Warm Climates-Results from a Large Scale Urban Mitigation Project. *Urban Climate, 24,* 326-339. https://doi.org/10.1016/j.uclim.2017.02.002

Lee, H., & Mayer, H. (2018). Maximum Extent of Human Heat Stress Reduction on Building Areas Due to Urban Greening. *Urban Forestry & Urban Greening, 32,* 154-167. https://doi.org/10.1016/j.ufug.2018.04.010

Lee, S. H., & Baik, J. J. (2010). Statistical and Dynamical Characteristics of the Urban Heat Island Intensity in Seoul. *Theoretical and Applied Climatology, 100,* 227-237. https://doi.org/10.1007/s00704-009-0247-1

Levermore, G. P. (2018). The Increasing Trend of the Urban Heat Island Intensity. *Urban Climate, 24,* 360-368. https://doi.org/10.1016/j.uclim.2017.02.004

Li, X., Zhou, W., & Ouyang, Z. (2013). Relationship Between Land Surface Temperature and Spatial Pattern of Greenspace: What Are the Effects of Spatial Resolution? *Landscape and Urban Planning, 114,* 1-8. https://doi.org/10.1016/j.landurbplan.2013.02.005

Lontorfos, V., Efthymiou, C., & Santamouris, M. (2018). On the Time Varying Mitigation Performance of Reflective Geoengineering Technologies in Cities. *Renewable Energy, 115,* 926-930. https://doi.org/10.1016/j.renene.2017.09.033

Luo, Z., & Asproudi, C. (2015). Subsurface Urban Heat Island and Its Effects on Horizontal Ground-Source Heat Pump Potential under Climate Change. *Applied Thermal Engineering, 90,* 530-537. https://doi.org/10.1016/j.applthermaleng.2015.07.025

Makar, P. A., Gravel, S., Chirkov, V., Strawbridge, K. B., Froude, F., Arnold, J., & Brook, J. (2006). Heat Flux, Urban Properties, and Regional Weather. *Atmospheric Environment, 40,* 2750-2766. https://doi.org/10.1016/j.atmosenv.2005.11.061

Mekala, G. D., Jones, R. N., & MacDonald, D. H. (2015). Valuing the Benefits of Creek Rehabilitation: Building a Business Case for Public Investments in Urban Green Infrastructure. *Environmental Management, 55,* 1354-1365. https://doi.org/10.1007/s00267-015-0471-7

Morakinyo, T. E., Lau, K. K. L., Ren, C., & Ng, E. (2018). Performance of Hong Kong's Common Trees Species for Outdoor Temperature Regulation, Thermal Comfort and Energy Saving. *Building and Environment, 137,* 157-170. https://doi.org/10.1016/j.buildenv.2018.04.012

Müller, N., Kuttler, W., & Barlag, A. B. (2014). Counteracting Urban Climate Change: Adaptation Measures and Their Effect on Thermal Comfort. *Urban Climate, 115,* 243-257. https://doi.org/10.1007/s00704-013-0890-4

Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S. G. (2015). Planning for Cooler Cities: A Framework to Prioritise Green Infrastructure to Mitigate High Temperatures in Urban Landscapes. *Landscape and Urban Planning, 134,* 127-138. https://doi.org/10.1016/j.landurbplan.2014.10.018

Parsaee, M., Joybari, M. M., Mirzaei, P. A., & Haghighat, F. (2019). Urban Heat Island, Urban Climate Maps and Urban Development Policies and Action Plans. *Environmental Technology & Innovation, 14,* Article 100341. https://doi.org/10.1016/j.eti.2019.100341

Qaid, A., Lamit, H. B., Ossen, D. R., & Shahminan, R. N. R. (2016). Urban Heat Island and Thermal Comfort Conditions at Micro-Climate Scale in a Tropical Planned City. *Energy and Buildings, 133,* 577-595. https://doi.org/10.1016/j.enbuild.2016.10.006

Rajagopalan, P., Lim, K. C., & Jamei, E. (2014). Urban Heat Island and Wind Flow Characteristics of a Tropical City. *Solar Energy, 107,* 159-170. https://doi.org/10.1016/j.solener.2014.05.042

Razzaghmanesh, M., Beecham, S., & Salem, T. (2016). The Role of Green Roofs in Mitigating Urban Heat Island Effects in the Metropolitan Area of Adelaide, South Australia. *Urban Forestry & Urban Greening, 15,* 89-102. https://doi.org/10.1016/j.ufug.2015.11.013

Ren, C., Ng, E. Y., & Katzschner, L. (2011). Urban Climatic Map Studies: A Review. *International Journal of Climatology, 31,* 2213-2233. https://doi.org/10.1002/joc.2237

Rizwan, A. M., Dennis, L. Y. C., & Chunho, L. I. U. (2008). A Review on the Generation Determination and Mitigation of Urban Heat Island. *Journal of Environmental Sciences, 20,* 120-128. https://doi.org/10.1016/S1001-0742(08)60019-4

Runhaar, H., Wilk, B., Persson, Å., Uittenbroek, C., & Wamsler, C. (2018). Mainstreaming Climate Adaptation: Taking Stock about "What Works" from Empirical Research Worldwide. *Regional Environmental Change, 18,* 1201-1210. https://doi.org/10.1007/s10113-017-1259-5

Santamouris, M., Cartalis, C., Synnefa, A., & Kolokotsa, D. (2015). On the Impact of Urban Heat Island and Global Warming on the Power Demand and Electricity Consumption of Buildings—A Review. *Energy and Buildings, 98,* 119-124. https://doi.org/10.1016/j.enbuild.2014.09.052

Santamouris, M., Ding, L., Fiorito, F., Oldfield, P., Osmond, P., Paolini, R., Prasad, D., & Synnefa, A. (2017). Passive and Active Cooling for the Outdoor Built Environment—Analysis and Assessment of the Cooling Potential of Mitigation Technologies Using Performance Data from 220 Large Scale Projects. *Solar Energy, 154,* 14-33. https://doi.org/10.1016/j.solener.2016.12.006

Santamouris, M., Haddad, S., Saliari, M., Vasilakopoulou, K., Synnefa, A. et al. (2018). On the Energy Impact of Urban Heat Island in Sydney: Climate and Energy Potential of Mitigation Technologies. *Energy and Buildings, 166,* 154-164. https://doi.org/10.1016/j.enbuild.2018.02.007

Sharma, A., Conry, P., Fernando, H. J. S., Hamlet, A. F., Hellmann, J. J., & Chen, F.

(2016). Green and Cool Roofs to Mitigate Urban Heat Island Effects in the Chicago Metropolitan Area: Evaluation with A Regional Climate Model. *Environmental Research Letters, 11,* Article 064004. https://doi.org/10.1088/1748-9326/11/6/064004

Taleghani, M., Crank, P. J., Mohegh, A., Sailor, D. J., & Ban-Weiss, G. A. (2019). The Impact of Heat Mitigation Strategies on the Energy Balance of a Neighborhood in Los Angeles. *Solar Energy, 177,* 604-611. https://doi.org/10.1016/j.solener.2018.11.041

Tan, Z., Lau, K. K. L., & Ng, E. (2016). Urban Tree Design Approaches for Mitigating Daytime Urban Heat Island Effects in a High-Density Urban Environment. *Energy and Buildings, 114,* 265-274. https://doi.org/10.1016/j.enbuild.2015.06.031

Toparlar, Y., Blocken, B., Maiheu, B., & Van, Heijst, G. J. F. (2017). A Review on the CFD Analysis of Urban Microclimate. *Renewable and Sustainable Energy Reviews, 80,* 1613-1640. https://doi.org/10.1016/j.rser.2017.05.248

Touchaei, A. G., Hosseini, M., & Akbari, H. (2016). Energy Savings Potentials of Commercial Buildings by Urban Heat Island Reduction Strategies in Montreal. (Canada). *Energy and Buildings, 110,* 41-48. https://doi.org/10.1016/j.enbuild.2015.10.018

Unger, J. (2004). Intra-Urban Relationship between Surface Geometry and Urban Heat Island: Review and New Approach. *Climate Research, 27,* 253-264. https://doi.org/10.3354/cr027253

Vahmani, P., Sun, F., Hall, A., & Ban-Weiss, G. (2016). Investigating the Climate Impacts of Urbanization and the Potential for Cool Roofs to Counter Future Climate Change in Southern California. *Environmental Research Letters, 11,* Article 124027. https://doi.org/10.1088/1748-9326/11/12/124027

Villanueva-Solis, J. (2017). Urban Heat Island Mitigation and Urban Planning: The Case of the Mexicali, BC Mexico. *American Journal of Climate Change, 6,* 22-39. https://doi.org/10.4236/ajcc.2017.61002

Wang, C., Wang, Z. H., Kaloush, K. E., & Shacat, J. (2021). Perceptions of Urban Heat Island Mitigation and Implementation Strategies: Survey and Gap Analysis. *Sustainable Cities and Society, 66,* Article 102687. https://doi.org/10.1016/j.scs.2020.102687

Wang, R., Peethambaran, J., & Chen, D. (2018). Lidar Point Clouds to 3-D Urban Models: A Review. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 11,* 606-627. https://doi.org/10.1109/JSTARS.2017.2781132

Wang, Y., & Akbari, H. (2016). Analysis of Urban Heat Island Phenomenon and Mitigation Solutions Evaluation for Montreal. *Sustainable Cities and Society, 26,* 438-446. https://doi.org/10.1016/j.scs.2016.04.015

Wang, Y., Berardi, U., & Akbari, H. (2016). Comparing the Effects of Urban Heat Island Mitigation Strategies for Toronto, Canada. *Energy and Buildings, 114,* 2-19. https://doi.org/10.1016/j.enbuild.2015.06.046

Whiteoak, K., & Saigar, J. (2019). *Estimating the Economic Benefits of Urban Heat Island Mitigation—Economic Analysis*. Cooperative Research Centre for Water Sensitive Cities.

Yang, J., Pyrgou, A., Chong, A., Santamouris, M., Kolokotsa, D., & Lee, S. E. (2018). Green and Cool Roofs' Urban Heat Island Mitigation Potential in Tropical Climate. *Solar Energy, 173,* 597-609. https://doi.org/10.1016/j.solener.2018.08.006

Zhang, L., Zhan, Q., & Lan, Y. (2018). Effects of the Tree Distribution and Species on Outdoor Environment Conditions in a Hot Summer and Cold Winter Zone: A Case Study in Wuhan Residential Quarters. *Building and Environment, 130,* 27-39. https://doi.org/10.1016/j.buildenv.2017.12.014

Zhang, Y., Gu, Z., & Yu, C. W. (2020). Impact Factors on Airflow and Pollutant Dispersion in Urban Street Canyons and Comprehensive Simulations: A Review. *Current Pollution Reports, 6,* 425-439. https://doi.org/10.1007/s40726-020-00166-0

Zhao, Q., Sailor, D. J., & Wentz, E. A. (2018). Impact of Tree Locations and Arrangements on Outdoor Microclimates and Human Thermal Comfort in an Urban Residential Environment. *Urban Forestry & Urban Greening, 32,* 81-91. https://doi.org/10.1016/j.ufug.2018.03.022